MEMOIRS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

VOL. IV.—PART I. pt. 2 p. 295

CAMBRIDGE:
PRINTED BY HILLIARD AND METCALF.
1818.

2

Pat 20
20167
688/

CONTENTS.

MEMOIRS

OF THE

AMERICAN ACADEMY.

Some account of the life and writings of Benjamin Count Rumford.

BY JACOB BIGELOW, M. D.

RUMFORD PROFESSOR IN HARVARD UNIVERSITY.

THE labours of mankind are generally efficient in proportion as they are concentrated, or devoted to a single object. In the present advanced state of philosophy and literature, excellence in any scientific career is usually attained at the price of a long and undivided attention to its particular pursuit. And if in certain instances individuals arrive at distinction in more than one walk of science, as well as of life, it may justly be ascribed to the greatness and versatility of their talents, or to the ardour, perseverance and resolution of their conduct.

In the subject of this memoir a singular example is found of success, attending natural talents and force of character, exerted in various situations of life, and under circumstances the most dissimilar. We can only suppose it to be from uncommon and commanding powers, aided by unusual activity; that an individual of obscure origin should rise above the disadvantages of his situation; should become possessed of high literary and political honors; and should maintain an uniform eminence in what-

ever sphere his exertions were required; whether in the closet or the laboratory, the court or the field.

The birth place of Benjamin Thompson, afterwards Count Rumford, was the town of Woburn in Massachusetts, a few miles from Boston. His parentage was from the common class of yeomanry, and the labours of agriculture still give employment to his surviving connexions in that place. His father dying during his infancy, he was put under the guardianship of a relation, from whom he received the ordinary advantages of a country school. His early taste is said by those who knew him during his boyhood, to have displayed itself in a fondness for mechanical and philosophical amusements. He was less captivated by the usual sports of boys, than he was by the construction of little pieces of mechanism, by rude attempts at drawing and painting, and the imitation of various articles of mechanics' work. In these occupations he engaged with great earnestness and perseverance, and was disturbed and impatient at any interruption of the pursuit. His propensity for employments of this kind was so strong, that it seems in a manner to have incapacitated him for more regular duties, and to have defeated the attempts which were made to initiate him in business.

At the age of thirteen, as it appears from a memorandum in his own hand writing, he was put apprentice in a merchant's store in Salem. Afterwards he spent a few months with a physician in Woburn, and at the age of sixteen again entered a merchant's counting-house in Boston. In all these situations he discovered an uniform disinclination for business, and a propensity to more eccentric pursuits. He privately amused himself in experiments with gunpowder and fire works, and laboured to

carry into execution a visionary project of perpetual motion. He was negligent of the concerns of his master and customers, that he might exercise his mechanical dexterity in various contrivances of art, or indulge his musical taste in performances on the violin and hautboy. These accomplishments not being of a kind to render him either useful or contented in the routine of a mercantile apprenticeship, he quitted his situation and returned to live with his mother at Woburn. "He was received by his acquaintance with unwelcome pity, as an unfortunate young man, who could not fix his mind on any regular employment, and who would never be able to support himself or afford consolation to his friends."

At the age of about 17, Mr. Thompson obtained permission to attend the lectures of Professor Winthrop on Natural Philosophy in the University at Cambridge, in company with his friend, the late Col. Baldwin, of Woburn. A rich field of information was thus opened to his inquisitive mind. To avail himself of the privilege, he was obliged constantly to walk from Woburn to Cambridge, a distance of nine miles, which exercise he performed in company with his friend, with unwearied punctuality and alacrity. He seems to have acquired here the rudiments of that philosophical knowledge which afterwards ripened into the source of so much honour to himself and benefit to the community.

At a subsequent period, he was engaged in the instruction of a country school at Bradford in Essex county. It was the pursuit of this calling which led our young philosopher to Concord, in New Hampshire, a place which became his residence, and furnished his future title. At Concord, his pecuniary situation was improved by a marriage at the age of 19, with Mrs.

Rolfe, widow of Col. Rolfe, a lady possessing a considerable country estate, and by whom he afterwards had one daughter, the present Countess of Rumford. From the period of this connexion, he appears to have enjoyed additional consideration in the society around him. Possessing the external qualifications necessary to conciliate esteem, a handsome and commanding person, and a captivating address and manner, he acquired respect and confidence from his equals and acquaintance. An aspiring temper which never deserted him in any subsequent period of his life, led him to cultivate the acquaintance of those whom fortune had placed in more elevated ranks of society. Governor Wentworth, of New Hampshire, was among the number with whom he had the success to ingratiate himself, and this new intimacy procured him the commission of a civil magistrate, and afterwards, of a major in the militia of the province.

At the commencement of the troubles which gave birth to the American revolution, Major Thompson had the misfortune to labour under suspicions of being unfriendly to the cause of American freedom. These suspicions had their origin almost wholly in his previous intimacy with individuals attached to the British side. They were nevertheless so strong, that they kindled into a degree of popular excitement against him, which he was more than once obliged to shift his residence to avoid. His real attachment, however, was always on the side of American liberty. He earnestly sought for a commission in the service of Congress, and continually consulted with his friends how he should avert or change the popular opinion which threatened to frustrate his really patriotic wishes. He was present at the battle of Lexington, where the first blood of the revolution was shed,

and afterwards remained for some months in the American camp at Cambridge. He demanded and received a court of inquiry into his conduct, which was held at Woburn in 1775, and by which he was honourably acquitted of any actions or designs inimical to the cause of his country. He renewed his exertions to procure a majority in a corps of artillery then forming at Cambridge, and while waiting in suspense for this appointment, he applied himself diligently to the study of military tactics, and the art of fortification. He was peculiarly instrumental by his efforts, in preserving the library and philosophical apparatus of the University, at a time when the colleges were occupied as barracks by the soldiery. At length, after remaining some time with the army in fruitless hope, and seeing the post of his ambition filled by a rival candidate, he retired in disgust from the scene of his defeated expectations. The qualities of his mind were ill calculated to brook the combined influence of disappointment and suspicion, and he resolved to embark as an adventurer for England, entrusting to fortune and to his own genius the allotment of his future destiny.

The evacuation of Boston by the troops under the command of Gen. Gage was an important event in the early history of the American revolution. Mr. Thompson happened to be the bearer of the official despatches announcing this event, to London. This circumstance furnished him at once an introduction to men high in influence and power. Such was the interest which at that time prevailed in regard to the state and disposition of the American colonies, that a man possessing intelligence and address, coming immediately from the scene of action, was a valuable and acceptable source of information. Mr. Thompson did

not fail to profit by the advantages of his situation. At the period when it would naturally be supposed, that an emigrant from the interior of America would be feasting his curiosity upon the novelties and splendor of London, he seems to have been occupied with the more substantial projects of laying a foundation of future eminence in life. He ingratiated himself so far with Lord George Germaine, that he obtained a situation in the colonial department, and in a few years became under secretary of state for the northern department. In the mean time he was so unwearied in his military studies and philosophical pursuits, that his talents in both these departments received honourable distinction. He became a member of the Royal Society in 1779, and in 1782 was appointed a colonel in the British army. In this last capacity he came out to America, and having organized his regiment, which was distinguished by the strictness of its discipline, he headed it in several skirmishes near Charleston, S. C. The conclusion of peace put an end to his military exploits. It is remarkable, that although he was absent from his native country during a great part of the war of independence, yet as a partizan of opposite sides he was present at the shedding of the first and last blood, which was spilt in the revolutionary contest.

Having returned to England, he remained some time in that country, devoting himself to philosophical inquiries and military improvements. During this period, he introduced a revision of the military exercise, and effected several reformations of acknowledged consequence. His passion, however, for active service in the field did not leave him, and in 1784 he quitted England on his way to Vienna, with a view to offer his services to Austria, then engaged in a war with the Turks. Previously

to his departure, he had received the honour of Knighthood from the king of Great Britain.

In more than one instance of his life it happened, that the fine manly figure and captivating manners of Colonel Thompson were instrumental in deciding his reception among strangers. On his journey to Vienna, he arrived at Manheim during a review of troops by the Duc de Deux Ponts, afterwards king of Bavaria. The English officer presented himself a spectator at this parade, on horseback, and equipped in the uniform of his rank. His appearance led to inquiries, which ended in his introduction to the Duke, and afterwards to the court of the reigning Elector Palatine at Munich. It has been stated by some, that the Elector Palatine had previously applied to the British government for a military man, properly qualified, to organize his army. However this may be, Sir Benjamin Thompson was received at Munich with very flattering attention, and his permanent stay at that place was strongly urged.

Bavaria at this time presented, in more than one respect, a fit theatre for the work of reformation. Abuses of various kinds prevailed among the retainers of power, while ignorance and idleness characterized the lower classes of society. In the army, a loose and imperfect discipline was kept up, the police of the cities was feeble and ill administered; and mendicity, which was exercised as a trade, had become one of the most alarming evils of the community. The enterprising spirit of Sir Benjamin led him, at an early period, to contemplate the reform of these abuses. His talents and experience in civil and military life, aided by the unbounded confidence with which he had inspired the Elector, rendered him a suitable person to undertake the performance of

so arduous a duty. His attention was first turned to the state of the army, which a long peace and a series of abuses had reduced to the shadow of a military force. Aided by the uniform support and countenance of the Elector, and not less by his own address and vigilance, he succeeded in effecting a new organization of the army, notwithstanding the opposition he was obliged to encounter from the jealousy and discontent of its officers. The clothing and food of the soldiery were improved, and their comforts increased; while at the same time the military expenses of the state were, by a prudent economy, diminished. The artillery underwent many new and original improvements; military schools were established, and the sciences were made to contribute fresh advantages to the art of war.

The prevalence of mendicity next arrested the attention of our reformer. This was an evil under which Munich suffered almost beyond any city in Europe. The streets were literally blocked up with beggars, and conspicuous or favourable posts for extorting charity were bought and sold as real property. A plan was formed and privately matured for eradicating this evil from the community by a single stroke. A house of industry was provided, containing preparations sufficient for the support and useful employment of all the mendicants in the city. On an appointed day all the beggars in Munich were arrested and brought before the magistrates; begging in future was positively prohibited, and they were informed that a place of refuge and employment was provided for them in the house of industry. The success of this plan fulfilled the most sanguine expectations of its projector. The establishment, which in the first instance was computed to have cost less than the sum annually extorted from the citizens as

charity, in a short time supported itself by its manufactures, and eventually yielded a considerable revenue to the state. All this was accomplished without oppression or hardship exercised on the poor themselves. Care was taken to render their situation comfortable and to excite their industry by judicious rewards. The system in the end became highly acceptable to the subjects of it, and expressions of satisfaction and of gratitude to its author, occasionally broke forth from these unfortunate beings. The author of this reform was sensibly alive to the acknowledgments of success, which rewarded his philanthropic exertions. He has feelingly described the effect produced on his mind, during a dangerous illness by a sound under his window, from a procession of the poor, who were going to church to put up prayers for the recovery of their benefactor.

The multiplied services which Sir Benjamin Thompson rendered in Bavaria, of the agricultural, scientific, political, and military kind, are too numerous for the limits of this memoir. They were munificently recompensed by the Elector Charles Theodore, who successively appointed him his aid-de-camp, chamberlain, member of his council of state, and lieutenant general of his armies. As the statutes of Bavaria did not permit his receiving the honors of knighthood in that country, the Elector procured for him the decorations of the two Polish orders, the White eagle, and St. Stanislaus. Lastly, in the interval between the death of the Emperor Joseph, and the coronation of Leopold II, the Elector profited by the right given him by his functions as vicar of the empire, to raise Sir Benjamin to the dignity of a Count of the Holy Roman empire. The title of Rumford, assumed by him on

this occasion, is taken from the original name of Concord in New Hampshire, the place of his early residence.

But honorary titles were not his only reward. He was intrusted with real and very extensive power in enjoining the united offices of minister of war and superintendant of the police. He had the entire command of the Bavarian army, in the noted campaign of 1796, in which, by his firmness and decision, he succeeded in preserving the neutrality of the capital against the attempts of two hostile armies, which successively threatened it. Finally, in 1798, he was appointed to a station which he had earnestly desired, that of minister plenipotentiary to the Court of London.

A most flattering prospect now presented itself to Count Rumford;—that of residing in London, the scene of his early greatness, in the enjoyment of a distinguished and honourable appointment in the service of a foreign court. Unfortunately however for his hopes, the etiquette of the English court did not admit a British born subject to be accredited as minister from another power, and Count Rumford was informed the custom could not be dispensed with in his case. This decision was a disappointment to his wishes, yet did not prevent his remaining in the country. He resided some years at London, engaged in various scientific inquiries and in introducing the improvements, which he had tested in Germany. His popularity at this period was very extensive, the essays which he published on philosophic subjects were generally read and admired, his economical improvements were every where fashionable, and the weight and ascendency of his character were such, that they enabled him to carry into effect some extensive and important innovations. The Royal Institution of Great Brit-

ain, founded in 1800, owes its existence to the influence and exertions of Count Rumford. The original charter was granted for the purpose of forming a "public institution for diffusing the knowledge and facilitating the general introduction of useful mechanical inventions and improvements; and for teaching by philosophical lectures and experiments the application of science to the common purposes of life."—Such was the origin of a school of philosophy which has been destined to attain the highest celebrity, and to diffuse the most important light upon various departments of science.

In the year 1796 Count Rumford had placed in the English funds one thousand pounds sterling, the interest of which was to be awarded in premiums by the Royal Society of Great Britain to the author of the most useful discovery on light and heat. A similar donation was placed in the American funds, the proceeds to be adjudged in prizes for the same purpose by the American Academy of Arts and Sciences. The following letter to the president of the Academy accompanied the donation.

"Sir,

"Desirous of contributing efficaciously to the advancement of a science which has long employed my attention, and which appears to me to be of the highest importance to mankind; and wishing at the same time to leave a lasting testimony of my respect for the American Academy of Arts and Sciences, I take the liberty to request that the Academy would do me the honour to accept of five thousand dollars three per cent. stock in the funds of the United States of North America, which stock I have actually purchased, and which I beg leave to transfer to the fellows of the Academy to the end, that the interest of the same may be

by them and by their successors received from time to time forever, and the amount of the same applied and given once every second year as a premium, to the author of the most important discovery or useful improvement, which shall be made and published by printing or in any way made known to the public in any part of the continent of America, or in any of the American islands during the preceding two years, on heat and on light; the preference always being given to such discoveries as shall in the opinion of the Academy tend most to promote the good of mankind.

"With regard to the formalities to be observed by the Academy in their decisions on the comparative merits of those discoveries, which, in the opinion of the Academy, may entitle their authors to be considered as competitors for this biennial premium, the Academy will be pleased to adopt such regulations as they in their wisdom may judge to be proper and necessary. But in regard to the form in which this premium is conferred, I take the liberty to request that it may always be given in two medals, struck in the same dye, the one of gold and the other of silver, and of such dimensions as that both of them together may be just equal in intrinsic value to the amount of the interest of the aforesaid five thousand dollars stock during two years; that is to say, that they may together be of the value of three hundred dollars.

"The Academy will be pleased to order such device or inscription to be engraved in the dye, they shall cause to be prepared for striking these medals, as they may judge proper.

"If during any term of two years, reckoning from the last adjudication, or from the last period for the adjudication of this premium by the Academy, no new discovery or improvement

should be made in any part of America relative to either of the subjects in question, heat or light, which in the opinion of the Academy shall be of sufficient importance to deserve this premium; in that case, it is my desire that the premium may not be given, but that the value of it may be reserved, and being laid out in the purchase of additional stock in the American funds, may be employed to augment the capital of this premium; and that the interest of the sums by which the capital may from time to time be so augmented, may regularly be given in money, with the two medals as an addition to the original premium, at each succeeding adjudication of it. And it is further my particular request, that those additions to the value of the premium arising from its occasional non-adjudications may be suffered to increase without limitation.

"With the highest respect for the American Academy of Arts and Sciences, and the most earnest wishes for their success in their labours for the good of mankind,

"I have the honour to be, with much esteem and regard,

Sir,

your most obedient,

humble servant,

RUMFORD."

London, July 12, 1796.

To the Hon. John Adams Esq.
President of the American
Academy of Arts and Sciences.

The premium intrusted to the Royal society of London has been several times adjudged to the authors of important discoveries on heat or light. That in the hands of the American Acad-

emy has never yet been awarded, no improvement or discovery having been presented which appeared deserving of the medal.

Count Rumford received while in Europe repeated invitations to revisit his native country, one of which was formally made by the government of the United States through their ambassador in London. To this invitation he returned an answer expressive of the deepest sense of gratitude and esteem, but declining the offer on the ground that engagements, rendered sacred and inviolable by great obligations, did not permit him to dispose of himself in such a manner as to accept the overtures made him.

The latter part of the Count's life does not appear to have been attended with the same undeviating good fortune which had formerly followed him. In Bavaria the death of his old benefactor and patron, the Elector Charles Theodore, was succeeded by a change of political interests, by which his influence at that court was essentially diminished. In England, he had a rupture with the managers of the Royal Institution, which materially affected his popularity in that country. These circumstances probably produced in him the definitive resolution to take up his abode in France, a country which seemed to offer scope for his pursuits and a due appreciation of his character.

In Paris, after a few years residence, he married Madame Lavoisier, widow of the celebrated chemist of that name, with whom he lived a short time. Unhappily this match had its origin in motives of ambition, rather than a congeniality of temper; and ended in a voluntary separation of the parties. Count Rumford took up his residence at Auteuil near Paris, where he continued engaged in various scientific inquiries and pursuits until his death. A violent attack of fever terminated his existence on the 21st of August 1814, and in the 62d year of his age.

His eulogy was pronounced by M. Cuvier on the 9th of January following his death, before the Institute of France.

By his will, Count Rumford bequeathed one thousand dollars annually, together with the reversion of his whole estate, to the University of Cambridge, in the state of Massachusetts in North America, for the purpose of founding under the direction and management of the Corporation, Overseers and Government of that University, a new Institution and Professorship, to teach by regular courses of academical and public lectures, accompanied with proper experiments, the utility of the physical and mathematical sciences, for the improvement of the useful arts, and for the extension of the industry, prosperity, happiness, and well being of society.

Count Rumford has left in his writings a memorial of great scientific industry, and a happy specimen of a popular mode of conveying philosophic instruction. His productions appeared at various periods of his life in the form of separate papers, principally in the Philosophical Transactions, and in the volumes of his Essays. The present occasion will not admit an examination of all his writings, and it is only practicable to notice some of his most conspicuous labours.

His earliest scientific publications seem to have been connected with improvements in the art of war, his attention at this time being chiefly occupied by military pursuits. His experiments on gunpowder throw some light on the laws which increase or diminish its force, many of which were practically known before to military men. He found by trial that a charge rammed down in a piece, produces greater effect than when it is inserted in a less compact manner. He also found that the heat which the gun ac-

quires by repeated firing, serves to increase the strength of the powder. He tried the effect of an admixture of various substances with gunpowder, to increase its force; such as carbonate of potash, sal ammoniac, brass filings, alcohol and water. These were all, however, found to diminish rather than increase the effect of the explosion. He calculated the force of fired gunpowder to be equal to fifty thousand atmospheres, a force much exceeding that ascribed to it by previous calculators, and which has since been thought to exceed the probable truth.

Count Rumford made many experiments on the conducting power of different substances for heat, with a view to their practical application in clothing, building, &c. It is, however, impossible to subject the different clothing stuffs, such as wool, silk, fur, down, &c. to very accurate experimental tests, since their conducting power must always vary in proportion to the closeness of their fabric. Thus a loose flannel will always be a worse conductor of heat than a compact or glazed cloth made of the same material in equal quantity. The general conclusions of the Count, however, are correct, that *cæteris paribus*, the finer the fibre is, the worse conductor will the stuff be which is composed of it. The non-conducting power of these substances is properly attributed to the air retained among the fibres by attraction of the capillary kind. The greater is the amount of air made stationary by this attraction, the better non-conductor will the substance become.

Being employed to superintend the boring of cannon at Munich, he availed himself of the occasion for experiments on the heat excited by friction. Having confined the end of the gun, while boring, in a box filled with water, he observed the change

of temperature produced in the fluid during the operation. A steel borer pressed against the metal of the gun, with a force equal to ten thousand pounds, while the gun revolved 32 times in a minute; caused the water in the box, amounting to 18 or 19 lbs. to boil in 2 hours and an half. The heat thus produced was as great as would have been given out by nine large wax candles burning all the time. The Count, concluding that no change took place in the specific heat of the metal, nor was any heat derived from the air; adopts the opinion, which has many supporters at the present day, that heat is a vibratory motion of the particles of a substance, and not a substance *sui generis.*

With a view to increase the comfort and usefulness of clothing, he made experiments to determine the relative quantities of moisture absorbed from the atmosphere by different materials in use for that purpose. He found that wool absorbs more moisture from the atmosphere than any substance used in clothing, and concludes that woollen clothes, such as flannels, worn next the skin greatly promote insensible perspiration, independently of their superior warmth. He considers the practice of wearing flannel to be highly salubrious not only in cold, but also in warm climates.

In an inquiry concerning the weight ascribed to heat, he found that bottles of different fluids, as mercury, alcohol and water, reremained in equilibrium during great changes of temperature, notwithstanding the very unequal quantities of caloric, which they must have lost, owing to their different capacities for heat. His experiments show that a quantity of heat equal to that which about ten ounces of gold would require to raise it from the temperature of freezing water to be red hot, produces no sensible effect upon a balance capable of indicating so small a variation of weight as

that of one millionth part of the body in question. This being the case, the Count concludes that we may very safely infer, that all attempts to discover any effect of heat upon the apparent weights of bodies will be fruitless.

The admeasurment of *light*, although necessary in all comparisons of the modes of illumination, is nevertheless an object which it is difficult to accomplish with accuracy. The Photometer of Count Rumford affords a very good method of comparing the intensity of any two luminous bodies giving light at the same time. The principle of this instrument consists in interposing an object between the illuminating bodies and a plain surface, on which it shall cast a shadow from both. The distance of the lights is then varied, until both the shadows become of equal intensity. The quantity of light emitted is to be estimated by the squares of the distance of the illuminating bodies from the object producing the shadows, on the principle that light decreases in proportion to the square of the distance.

Some experiments relating to the transmission of heat through liquids led the Count to suppose that fluids are non conductors of heat, and that heat is transmitted through them by the motion or change of place which occurs among their particles. This opinion however has been set aside in consequence of the experiments of later chemists, and the Count himself is said ultimately to have given it up.

But the most valuable of Count Rumford's researches, and those which seem to have shed the most imperishable glory upon his name, are not so much his attempts at developing new laws of matter, as his successful and fortunate application of those already known to the use and convenience of mankind. In the

former he was not always original, and some of his conclusions have not stood the test of subsequent examination. In the latter however his genius was fertile and efficient. His plans of utility have been so well conceived and happily executed, that they have carried conviction of their importance to every examiner; they have been almost universally adopted, and are now silently operating in most parts of the civilized world. The management and economy of heat, whether for the purpose of warming habitations or of conducting manufacturing and culinary processes; formed the subject of many interesting essays, which it is not practicable to analyze in this place. It is well known that his fire places afford the most perfect form for radiating the heat of the fire into apartments to be warmed; that his boilers, ovens, &c. concentrate and direct the heat with great effect, and with wonderful economy of means. He has availed himself of the smoke of his fuel, and of the steam of water, to effect what was formerly done by the combustion of fresh materials. So important are his improvements, that in some cases the amount of fuel consumed to answer a given purpose is reduced to a fourth and even an eighth part of what was before necessary.

His establishments for the support of the poor at Munich, which he has described in his essays, are undoubtedly among the most successful attempts at ameliorating the condition of a wretched class of society, with the least expense to those on whom their support devolves. His account of the arrangements made for accommodating clothing, feeding and employing the poor at Munich, occupies nearly a volume of his essays. He particularly details the manner in which the paupers and mendicants of that city were arrested, the disposal of them in the house of industry,

their employments, and the modes used to overcome their awkwardness and reluctance, and reconcile them to their situation. He acquaints us with the judicious means employed to excite their emulation and encourage their industry, and gives many proofs that the attempts made to render them diligent, comfortable and comparatively happy, were fully successful. He has given a full discussion of the various modes of producing large quantities of nourishment from small and cheap materials; and has gone into a long examination of the comparative quantities of nutriment afforded by the common articles of diet, and of the different modes of preparing them to the greatest advantage. He has given a distinct essay upon a subject not usually much regarded in the maintenance of the poor—"The pleasure of eating and the means that may be employed for increasing it."

Among the latest publications of this philosopher is memoir read to the French Institute in 1811, on the means of improving the construction of wheel carriages. In this paper he endeavours to prove, that every description of coaches, chaises, wagons, &c. may be rendered more easy to the rider and less laborious to the horses, by employing wheels with a broad circumference, instead of the narrow or thin wheels now in use. For the several last years of his life he rode in a carriage having wheels of this kind, and has satisfactorily demonstrated their superior advantage in most cases. It is obvious that a broad wheel in passing over a pavement will sink less frequently into the cavities between the stones, than one which is narrow. This difference may even be observed between a chaise wheel which is newly shod, and one, the angles of which are worn off by use. In a soft or sandy road, a broad wheel will also sink less deeply than a narrow one. So

that a carriage having wheels of this construction will move in a more uniformly horizontal line, than one which by its construction sinks frequently, or cuts deeply. In order to put the question to an experimental test, Count Rumford contrived an elastic apparatus, connecting his carriage with the horses, which changed its situation in proportion to the difficulty of the draught, and pointed out by an index the quantity of force expended by the horses. In three sets of wheels of different width employed in the experiments, the broadest always required the least force in the draught, while the narrowest required most. Those who attend to this subject will perceive that on pavements, or in sandy or muddy roads, the preference must be given to wheels with the broad circumference. But on the other hand, in rough or stony roads, it is obvious that a broad wheel will strike many obstacles which a narrow one would escape.

It was not only in his equipage, but in his house, his apparel, and his mode of life; that Count Rumford pursued a plan of philosophic fitness and undeviating precision. The furniture of his house was arranged in the order of complementary colours, his culinary utensils were inventions of his own, his clothing was cut by the model of convenience, his food and drink were taken by rule. He considered *order* as the principal virtue, and the chief instrument of human happiness; and his wants and gratifications were as rigidly measured, as his time, and his mental and bodily labours. In military life his discipline had been rigid to the extreme, and in private situations he studied the most scrupulous punctuality and method himself, and exacted an observance of the same virtues from those around him.

The character of Count Rumford appears to have undergone changes at different periods of his life, which are not unusual in men passing through the different grades of consideration in society. In youth, while his ambition was flattered, and the prospects of honorable life were expanding before him; his deportment was marked by affability and condescension, suavity of address, and conciliating manners. As his elevation in life advanced, and his situation became more consequential; his demeanor was authoritative, and a regard for the feelings and interests of others became a less prominent part of his character. Though never indifferent to fame, he disregarded the personal esteem of those with whom he was connected, and separated under unfavourable circumstances from acquaintance of his earlier years, from institutions he had founded, and from the nearest connexions of domestic life. His last years were marked by an austerity of manner, and an inflexible pertinacity of opinion and conduct. He had never counted on the gratitude of mankind, and believed that a man could not long be honoured in the place of his residence. It was perhaps fortunate for him that the resource of self-respect never deserted him with any change of popular or individual regard.

It is enough for us that he has laboured with assiduity and success for the noblest of temporary objects, the extension of science and the welfare of mankind. When the blemishes of private life are exceeded and eclipsed by important public services, it does not become the recorders of posthumous character to intrude them upon the light, or by dwelling on them, to exaggerate their deformity. Few characters can bear the ordeal of such a scrutiny. Few men have risen to the highest stations in society without the exercise of policy and vigilant self-love, without some-

times being unjust to the interfering claims of others, and without sometimes disregarding those humble and silent virtues which are stumbling blocks in the path of ambition. Yet, if examples of perfect character are rare among mankind, there is no cause that we should not hold up to imitation at least the semblance of perfection. When the grave has closed upon individual greatness, we should see if there is not in the whole more of character to applaud and imitate, than to censure and avoid. For the excitement of emulation, it is better that useful and honorable actions should be presented to view unblemished by the stain of cotemporary faults. The frailty of human nature demands that justice should lean to the side of lenity. And if in common cases this principle may operate, how much more should the failings of him be buried in oblivion, who has left to cover them, a monument of public virtue and philosophic greatness.

I.

A NEW INVESTIGATION OF KEPLER'S PROBLEM,

BY F. T. SCHUBERT.

Communicated August 13, 1817.

§ 1. This famous Problem has the same relation to that part of Astronomy, commonly called *theoretical*, which the Problem of *three bodies* has to the *physical* part of Astronomy. It contains, *in nuce*, the laws of Kepler, or the whole theory of that part of the science, which explains the true motions of the celestial bodies, in the same manner, as the Problem of three bodies comprehends the Newtonian theory of gravitation. After it is theoretically resolved, it is still, *in praxi*, subjected to so many difficulties, arising from the complicated calculation it requires, that every attempt to render it more simple, will be favourably received by astronomers. It is true, we have already many solutions of this Problem; but after a full consideration of the subject, I am of opinion, that the only method strictly mathematical is that, used by Laplace in his immortal work (*Mécanique Céleste, tom.* i. p. 170. *et seq.*) in which we proceed by a straight course, and may stop or advance, whenever we please; whereas the other methods lead us with difficulty through bye-paths, and oblige us to determine, in the very beginning of the computation, the degree of accuracy which we mean to attain, so that, afterwards, it is not in our power to bring the calculus to a higher degree of accuracy,

without recommencing the whole operation. The method of Laplace is, in fact, only an application of the analytical theory of *Functions*, or Taylor's famous Theorem, which is so useful in all branches of mathematics. But, since the author of the *Mécanique Céleste* has not gone through the whole calculus, and has, moreover, treated the theory of Functions in a more general point of view, than what this Problem requires; it seems, that a full and clear elucidation of this Problem will not be useless. Besides, it will be found in the latter part of this paper, that I have treated the subject in a manner, which is quite new.

§ 2. Let the semi-major axis of the elliptical orbit of a Planet be equal to 1; the *eccentricity* e, the *radius vector* z, the *mean*, the *eccentrical*, and the *true anomaly*, supposed to be counted from the Perihelium, μ, ϵ, v: then the resolution of Kepler's Problem will be contained in the three following equations:

$$\text{I. } o = \epsilon - e \sin \epsilon - \mu; \qquad \text{II. } \tang \frac{v}{2} = \tang \frac{\epsilon}{2} \cdot \sqrt{\frac{1+e}{1-e}};$$

$$\text{III. } z = 1 - e \cos \epsilon,$$

by the help of which, v and z are to be found from the given angle μ. When we have no other object, than to calculate astronomical tables, the most natural and easy way is undoubtedly, first to find ϵ from μ, by means of the equation I, for which purpose there are several well known indirect methods; and then, to calculate directly v and z from ϵ, by means of the equations II and III. But, in the calculus of the perturbations, it is necessary to develop v and z in series proceeding according to the powers of e and depending upon the angles μ, 2μ, 3μ, etc. The investigation of these series is the real object of our problem.

I shall begin with seeking v from ϵ, by means of the equation II, in order to know the form or nature of the function, to which the general theory of functions is to be applied.

§ 3. If c be the number 2,718....., the hyperbolical logarithm of which is $=1$; we shall have by analytical Trigonometry the following equations:

$$\sin x = \frac{c^{x\sqrt{-1}} - c^{-x\sqrt{-1}}}{2\sqrt{-1}}, \qquad \cos x = \frac{c^{x\sqrt{-1}} + c^{-x\sqrt{-1}}}{2},$$

$$\tan x = \frac{c^{2x\sqrt{-1}} - 1}{(c^{2x\sqrt{-1}}+1)\sqrt{-1}}.$$

Thence by substituting $\frac{v}{2}$ and $\frac{\varepsilon}{2}$ in the place of x, and $\sqrt{\frac{1+e}{1-e}} = \delta$, in the equation II, we shall obtain $\frac{c^{v\sqrt{-1}}-1}{c^{v\sqrt{-1}}+1} = \delta \cdot \frac{c^{\varepsilon\sqrt{-1}}-1}{c^{\varepsilon\sqrt{-1}}+1}$,

whence arises $c^{v\sqrt{-1}} = \frac{(\delta+1)c^{\varepsilon\sqrt{-1}} - (\delta-1)}{(\delta+1)-(\delta-1)c^{\varepsilon\sqrt{-1}}}$.

If $\frac{\delta-1}{\delta+1}$ is called λ, we shall have $\lambda = \frac{\sqrt{(1+e)}-\sqrt{(1-e)}}{\sqrt{(1+e)}+\sqrt{(1-e)}}$, and by multiplying both the Numerator and Denominator by the latter,

$\lambda = \frac{(1+e)-(1-e)}{(1+e)+2\sqrt{(1-e^2)}+(1-e)} = \frac{e}{1+\sqrt{(1-e^2)}}$; whence by dividing the Numerator and Denominator of $e^{v\sqrt{-1}}$ by $\delta+1$, we get

$$c^{v\sqrt{-1}} = \frac{c^{\varepsilon\sqrt{-1}}-\lambda}{1-\lambda c^{\varepsilon\sqrt{-1}}} = c^{\varepsilon\sqrt{-1}} \cdot \frac{1-\lambda c^{-\varepsilon\sqrt{-1}}}{1-\lambda c^{\varepsilon\sqrt{-1}}}.$$

By taking the logarithms of these equal quantities, and putting $lc=1$, $\quad v = \varepsilon + \frac{l(1-\lambda c^{-\varepsilon\sqrt{-1}}) - l(1-\lambda c^{\varepsilon\sqrt{-1}})}{\sqrt{-1}}$.

If we now make use of the well known series,

$l(1-x) = -x - \frac{x^2}{2} - \frac{x^3}{3} - \ldots - \frac{x^n}{n}$, we obtain

$$l(1-\lambda c^{-\varepsilon\sqrt{-1}}) - l(1-\lambda c^{\varepsilon\sqrt{-1}}) =$$

$$\lambda(c^{\varepsilon\sqrt{-1}} - c^{-\varepsilon\sqrt{-1}}) + \frac{\lambda^2}{2}(c^{2\varepsilon\sqrt{-1}} - c^{-2\varepsilon\sqrt{-1}}) + \ldots + \frac{\lambda^i}{i}(c^{i\varepsilon\sqrt{-1}} - c^{-i\varepsilon\sqrt{-1}});$$

whence by substituting $\frac{c^{x\sqrt{-1}} - c^{-x\sqrt{-1}}}{\sqrt{-1}} = 2\sin x$, we get

(A) $v = \epsilon + 2\lambda \sin\epsilon + \frac{2}{2}\lambda^2 \sin 2\epsilon + \ldots\ldots + \frac{2}{i}\lambda^i \sin i\epsilon$; the letter i denoting every *integer* affirmative number.

§ 4. Since the equation (A.) gives v in ϵ and sin $i\epsilon$, our problem is now reduced to this, to develop ϵ as well as sin $i\epsilon$ in series proceeding according to the powers of e, which must be performed by the help of the equation I. If, therefore, as is the case in our problem, μ is given, there will be found in every planetary orbit, according to the greater or less degree of its eccentricity, different values of ϵ, corresponding to the same given angle μ. Whence it follows, that μ is to be regarded as a constant or given quantity, and ϵ as a function of e. If we then put $e = x$, $\epsilon = y$, y will be a function of x, and the equation I will have the following form, $o = y - x \sin y - \mu$, by means of which we are to investigate y, or $\sin iy$, or any other function of y. Moreover sin y being also a function of y, the equation I agrees with the more general one, (1) $o = y \times x \,.\, \varphi(y) - a$, by which $\psi(y)$ is to be developed in a series proceeding according to the powers of x; $\varphi(y)$ and $\psi(y)$ being any two functions of y, instead of which we shall write, for the sake of brevity, φ and ψ.

§ 5. However difficult the general solution of the equation (1) may be, on account of the nature of the function φ, there will always occur particular cases, where its solution has no difficulty; as for instance, supposing $x = o$, we shall find immediately $y = a$, consequently $\psi(y) = \psi(a)$. But as soon as it is known that in a particular case in which $x = b$, $\psi(y)$ becomes equal to c. We shall have in every other case, in which $x = b + h$, according to Taylor's Theorem,

$$\psi(y) = c + h \,.\, \frac{d\psi}{dx} + \frac{h^2}{1\,.\,2} \,.\, \frac{dd\psi}{dx^2} + \ldots\ldots + \frac{h^n}{1\,.\,2\ldots n} \,.\, \frac{d^n\psi}{dx^n}.$$

Supposing now $b = o$, consequently $h = x$, we shall obtain

$$(2)\ \psi(y) = u + x.u_1 + \frac{x^2}{1.2.}u_2 + \ldots + \frac{x^n}{1.2\ldots n}u_n;$$

the letters $u, u_1, u_2, \ldots u_n$, denoting the value of the function $\psi(y)$, and its differentials or fluxions, $\frac{d\psi}{dx}, \frac{dd\psi}{dx^2}, \ldots \frac{d^n\psi}{dx^n}$, in the particular case when $x = o$.

§ 6. The differentials of the functions of y, φ, ψ, are necessarily of this form: $d\varphi = \varphi'.dy$, $d\psi = \psi'.dy$, $d\varphi' = \varphi''.dy$, $d\psi' = \psi''.dy$, and so on; therefore, since y is a function of x, (§ 4), we obtain $\frac{d\psi}{dx} = \frac{d\psi}{dy}.\frac{dy}{dx} = \psi'.\frac{dy}{dx}$, etc. A continual differentiation will therefore give us the following equations:

$$(3)\begin{cases} \frac{d\psi}{dx} = \psi^1.\frac{dy}{dx}; \qquad \frac{dd\psi}{dx^2} = \psi''\left(\frac{dy}{dx}\right)^2 + \psi^1.\frac{ddy}{dx^2}; \\ \frac{d^3\psi}{dx^3} = \psi'''.\left(\frac{dy}{dx}\right)^3 + 3\,\psi''.\frac{dy}{dx}.\frac{ddy}{dx^2} + \psi'.\frac{d^3y}{dx^3}; \\ \frac{d^4\psi}{dx^4} = \psi''''.\left(\frac{dy}{dx}\right)^4 + 6\,\psi'''.\left(\frac{dy}{dx}\right)^2.\frac{ddy}{dx^2} + 3\,\psi''.\left(\frac{ddy}{dx^2}\right)^2 + 4\psi''.\frac{dy}{dx}.\frac{d^3y}{dx^3} + \psi'.\frac{d^4y}{dx^4}; \text{ etc.} \end{cases}$$

Moreover, a continual differentiation of the equation (1)

$o = y + x.\phi - a$, gives

$o = (1 + x.\varphi')\,dy + \phi.dx$; $o = (1 + x.\varphi')\,ddy + x.\varphi''.dy^2 + 2\,\varphi'.dxdy$;

$o = (1 + x.\varphi')\,d^3y + 3x.\varphi''.dyddy + x.\phi'''.dy^3 + 3\,\varphi'.dxddy + 3\,\phi''.dxdy^2$, etc.

or since $x = o$ (§ 5),

$o = dy + \varphi.dx$; $o = ddy + 2\,\varphi'.dxdy$; $o = d^3y + 3\,\varphi'.dxddy + 3\,\varphi''.dxdy^2$; etc.

the first of which gives $\frac{dy}{dx} = -\varphi$; which value being substituted in the following equation, and so on, we shall obtain

$$(4)\begin{cases} \frac{dy}{dx} = -\varphi; \quad \frac{ddy}{dx^2} = +2\,\varphi.\varphi'; \quad \frac{d^3y}{dx^3} = -6\,\varphi.(\varphi')^2 - 3\,(\varphi)^2.\varphi''; \\ \frac{d^4y}{dx^4} = +24\,\varphi.(\varphi')^3 + 36\,(\varphi)^2.\varphi'.\varphi'' + 4\,(\varphi)^3.\varphi'''; \text{ etc.} \end{cases}$$

If we substitute these values in the equation (3), we shall obtain

$$\frac{d\psi}{dx} = -\psi'.\phi; \qquad \frac{dd\psi}{dx^2} = +\psi''.(\phi)^2 + 2\psi'.\phi.\phi';$$

$$\frac{d^3\psi}{dx^3} = -\psi'''.(\phi)^3 - 6\psi''.(\phi)^2.\phi' - 6\psi'.\phi.(\phi')^2 - 3\psi'.(\phi)^2.\phi'';$$

$$\frac{d^4\psi}{dx^4} = +\psi''''.(\phi)^4 + 12\psi'''.(\phi)^3.\phi' + 36\psi''.(\phi)^2.(\phi')^2 + 12\psi''.(\phi)^3.\phi'' + 24\psi'.\phi.(\phi')^3$$

$$+ 36\psi'.(\phi)^2.\phi'.\phi'' + 4\psi'.(\phi)^3.\phi'''; \text{ and so on.}$$

But it is evident, by the common rules of the *calculus differentialis*, that these expressions are susceptible of a much more simple form, thus:

$$(5)\begin{cases} \dfrac{d\psi}{dx} = -\psi'.\phi; \quad \dfrac{dd\psi}{dx^2} = +\dfrac{d.\psi'.(\phi)^2}{dy}; \quad \dfrac{d^3\psi}{dx^3} = -\dfrac{dd.\psi'(\phi)^3}{dy^2}; \\ \dfrac{d^4\psi}{dx^4} = +\dfrac{d^3.\psi'(\phi)^4}{dy^3} \text{ and so on.} \end{cases}$$

By substituting these values in the equation (2) (§ 5), we obtain

$$(6)\ \psi = u - x.\psi'.\phi + \frac{x^2}{1.2}.\frac{d.\psi'(\phi)^2}{dy} - \frac{x^3}{1.2.3.}.\frac{dd.\psi'(\phi)^3}{dy^2} + \text{etc.}$$

the letters ψ', ϕ, and their differentials denoting the particular value, which these functions have when $x = o$, whence,

$$y = a,\ u = \psi(a), \qquad \psi' = \frac{d.\psi(a)}{da}, \qquad \phi = \phi(a), \text{ (§ 5).}$$

§. 7. The application of this formula to Kepler's Problem has no other difficulty, than the length of the calculation. We have only to compare the equation I, $o = \epsilon - e \sin \epsilon - \mu$, with (1) $o = y + x \cdot \phi - a$, whence we get

$$x = -e,\ a = \mu, \quad y = \epsilon, \quad \phi = \sin \epsilon.$$

Let, in the first place, the sought function be ϵ (§ 4): then we shall have $\psi(y) = y = \epsilon$, $\quad \psi(a) = a = \mu$, $\quad \psi' = \dfrac{dy}{dy} = 1$,

$\phi(a) = \sin \mu$; and the equation (6) will be transformed into

$$\text{(B)} \quad \epsilon = \mu + e \sin \mu + \frac{e^2}{1.2}\frac{d.\sin^2 \mu}{d\mu} + \ldots + \frac{e^n}{1.2\ldots n}.\frac{d^{n-1}.\sin^n \mu}{d\mu^{n-1}}.$$

If, in the second place, $\sin i\iota$ be sought (§ 4), we shall have

$$\psi(y)=\sin iy=\sin i\iota, \quad \psi'=\frac{d\,\psi}{d\,\mu}=i\,.\cos i\iota, \quad y=a=\mu, \quad u=\psi(a)=\sin i\mu,$$

and the equation (6) becomes

$$\text{(C)} \quad \sin i\iota=\sin i\mu+ei\,.\cos i\mu\sin\mu+\frac{e^2}{1\,.\,2}\,.\,i\,.\frac{d\,.\cos i\mu\,.\sin^2\mu}{d\mu}+\ldots$$

$$+\frac{e^n}{1\,.\,2\ldots n}\,.\,i\,.\frac{d^{n-1}\cos i\mu\sin^n\mu}{d\mu^{n-1}}.$$

Therefore we must seek a general expression of the differentials $d^{n-1}\,.\sin^n\mu$, and $d^{n-1}\,.\cos i\mu\sin^n\mu$; for which purpose we must develop the quantity $\sin^n\mu$ or $(\sin\mu)^n$ into a series, proceeding according to the multiples of the angle μ.

§ 8. Analytical Trigonometry affords four different series, according as the number n has the form $4r$, $4r+2$, $4r+1$, or $4r+3$, viz.

$$(7)\ 2^{n-1}\,.\sin^n\mu=$$

$$\begin{cases} +\cos n\mu-N_1\cos(n-2)\mu+N_2\cos(n-4)\mu-\ldots-N_{\frac{n-2}{2}}\cos 2\mu+\frac{1}{2}N_{\frac{n}{2}}; \\ -\cos n\mu+N_1\cos(n-2)\mu-N_2\cos(n-4)\mu+\ldots-N_{\frac{n-2}{2}}\cos 2\mu+\frac{1}{2}N_{\frac{n}{2}}; \\ +\sin n\mu-N_1\sin(n-2)\mu+N_2\sin(n-4)\mu-\ldots+N_{\frac{n-1}{2}}\sin\mu; \\ -\sin n\mu+N_1\sin(n-2)\mu-N_2\sin(n-4)\mu+\ldots+N_{\frac{n-1}{2}}\sin\mu; \end{cases}$$

$$N_1=\frac{n}{1}, \quad N_2=\frac{n(n-1)}{1\,.\,2}, \ldots N_{\frac{n}{2}}=\frac{n(n-1)(n-2)\ldots(\frac{n}{2}+1)}{1\,.\,2\,.\,3\ldots\ldots\frac{n}{2}}, \text{ etc.}$$

being the well known coefficients or multiplers of each term of a Binomial raised to the power n.

In order to find the $(n-1)$th differential of these series, the differential of the first must be taken $(4r-1)$ times, because $n=4r$, the second series $(4r+1)$ times, the third $(4r)$ times, the fourth $(4r+2)$ times, and the form of the differentials will be discovered, as soon as the differential of the first series is taken three times, the second once, the third four times or not at all, and the fourth twice, because after four successive differentiations, we

again obtain the same form. Wherefore the third series will be the general form of the $(n-1)$th differential of all four series; and, since at each differentiation every term is to be multiplied by the coefficient of its angle μ, we shall obtain, in all four series, the same equation, viz.

$$(8)\ 2^{n-1}.\frac{d^{n-1}\sin^n\mu}{d\mu^{n-1}}=n^{n-1}\sin n\mu-N_1(n-2)^{n-1}\sin(n-2)\mu+N_2(n-4)^{n-1}\sin(n-4)\mu-\text{etc.}$$

which series terminates, when it arrives at μ or 2μ.

§ 9. Putting successively $n=2$, $n=3$, etc. and substituting the series (8), after having divided it by 2^{n-1}, in the equation (B) (§ 7), we obtain

$$(D)\ \epsilon=\mu+e\sin\mu+\frac{e^2}{1.2}\sin 2\mu+\frac{1}{2^2}.\frac{e^2}{1.2.3}(3^2.\sin 3\mu-3\sin\mu)+\ldots.$$

$$+\frac{1}{2^{n-1}}.\frac{e^n}{1.2\ldots n}\left[\begin{array}{l}n^{n-1}\sin n\mu-N_1(n-2)^{n-1}\sin(n-2)\mu+N_2(n-4)^{n-1}\sin(n-4)\mu\\ -\ldots\ldots\pm N_r(n-2r)^{n-1}\sin(n-2r)\mu,\end{array}\right]$$

in which the upper or lower sign, prefixed to N_r, is to be used, according as the number r is even or odd, and the whole series terminates, when $n-2r$ becomes equal to 2 or to 1. The same notation will be used in the rest of this paper, so that, whenever there occurs a double sign $\pm$ or $\mp$, the upper or lower is to be made use of, according as the exponent at the bottom of the next following coefficient N, (or whatever it may be,) is an even or odd number. This very essential remark must be well remembered.

§ 10. Suppose, for instance, the development of ϵ is desired as far as the twelfth power of e, then the equation (D) will give

$$\epsilon=\mu+e\sin\mu+\frac{e^2}{2}\sin 2\mu+\frac{e^3}{8}(3\sin 3\mu-\sin\mu)+\frac{e^4}{6}(2\sin 4\mu-\sin 2\mu)$$

$$+\frac{e^5}{2^7.3}(5^5.\sin 5\mu-3^4.\sin 3\mu+2\sin\mu)+\frac{e^6}{2^4.3.5}(3^4.\sin 6\mu-2^6.\sin 4\mu+5.\sin 2\mu)$$

$$+\frac{e^7}{2^{10}.3^2.5}(7^5.\sin 7\mu-5^6.\sin 5\mu+3^7.\sin 3\mu-5\sin\mu)$$

$$+\frac{e^8}{2^4.3^2.5.7}(2^{11}.\sin 8\mu - 3^7.\sin 6\mu + 2^6.7.\sin 4\mu - 7\sin 2\mu)$$
$$+\frac{e^9}{2^{15}.3^2.5.7}(3^{14}.\sin 9\mu - 7^8.\sin 7\mu + 2^2.5^8.\sin 5\mu - 2^2.3^7.7.\sin 3\mu + 2.7.\sin\mu)$$
$$+\frac{e^{10}}{2^8.3^4.5^2.7}(5^9.\sin 10\mu - 2^{19}.5.\sin 8\mu + 3^{11}.5\sin 6\mu - 2^{12}.3.5.\sin 4\mu + 2.3.5.7.\sin 2\mu)$$
$$+\frac{e^{11}}{2^{18}.3^4.5^2.7}(11^9.\sin 11\mu - 3^{20}.\sin 9\mu + 5.7^{10}\sin 7\mu - 3.5^{11}.\sin 5\mu + 2.3^{11}.5.\sin 3\mu - 2.3.7.\sin\mu)$$
$$+\frac{e^{12}}{2^8.3^4.5^2.7.11}(2^9.3^{10}\sin 12\mu - 5^{11}\sin 10\mu + 2^{21}.11.\sin 8\mu - 3^{10}.5.11.\sin 6\mu + 2^9.3.5.11.\sin 4\mu - 2.3.11\sin\mu)$$

§ 11. In order to develop sin $i\epsilon$ in a like manner, we must make use of the product cos $i\mu$. sin$^n\mu$ (C) (§ 7). Therefore, the series (7) (§ 8) is to be multiplied by cos $i\mu$, which being done, each term of the two first series, which will have the form cos $i\mu$ cos $k\mu$, must be put equal to $\frac{1}{2}\cos(k+i)\mu + \frac{1}{2}\cos(k-i)\mu$, and instead of each term of the third and fourth series, *viz.* cos $i\mu$ sin $k\mu$, we must substitute $\frac{1}{2}\sin(k+i)\mu + \frac{1}{2}\sin(k-i)\mu$, according to the well known rules of Trigonometry. Hence arises

(9) $2^n.\cos i\mu \sin^n\mu =$

$$\begin{cases} +\cos(n+i)\mu+\cos(n-i)\mu-N_1\cos(n-2+i)\mu-N_1\cos(n-2-i)\mu+\ldots+N_{\frac{n}{2}}\cos i\mu\,; \\ -\cos(n+i)\mu-\cos(n-i)\mu+N_1\cos(n-2+i)\mu+N_1\cos(n-2-i)\mu-\ldots+N_{\frac{n}{2}}\cos i\mu\,; \\ +\sin(n+i)\mu+\sin(n-i)\mu-N_1\sin(n-2+i)\mu-N_1\sin(n-2-i)\mu+\ldots+N_{\frac{n-1}{2}}(\sin(1+i)\mu+\sin(1-i)\mu); \\ -\sin(n+i)\mu-\sin(n-i)\mu+N_1\sin(n-2+i)\mu+N_1\sin(n-2-i)\mu-\ldots+N_{\frac{n-1}{2}}(\sin(1+i)\mu+\sin(1-i)\mu); \end{cases}$$

Since these series have exactly the same form as that of (7) (§ 8), they will in like manner give

$$(10)\ 2^n.\frac{d^{n-1}.\cos i\mu\sin^n\mu}{d\mu^{n-1}} = (n+i)^{n-1}\sin(n+i)\mu+(n-i)^{n-1}\sin(n-i)\mu$$
$$-N_1[(n-2+i)^{n-1}\sin(n-2+i)\mu+(n-2-i)^{n-1}\sin(n-2-i)\mu]+\ldots$$
$$\pm N_r[(n-2r+i)^{n-1}\sin(n-2r+i)\mu+(n-2r-i)^{n-1}\sin(n-2r-i)\mu]\,;$$

which series terminates, when $n-2r$ is equal to 0 or to 1. In the latter case, the last term becomes =

$\pm N_{\frac{n-1}{2}}[(1+i)^{n-1}\sin(1+i)\mu+(1-i)^{n-1}\sin(1-i)\mu]$; in the former, this term is only $= \pm N_{\frac{n}{2}}.\, i^{n-1}.\sin i\mu$.

§ 12. If we put successively $n=2$, $n=3$, etc. and substitute the series (10), divided by 2^n, in the equation (C) (§ 7), there arises

$$\text{(E)} \quad \sin i\,\epsilon = \sin i\mu + \tfrac{i}{2}\,e\,(\sin(1+i)\mu + \sin(1-i)\,\mu$$
$$+ \frac{i}{2^2}\cdot\frac{e^2}{1.2}\Big((2+i)\sin(2+i)\mu + (2-i)\sin(2-i)\,\mu - 2\,i\sin i\mu\Big) + \dots$$
$$+ \frac{i}{2^n}\cdot\frac{e^n}{1.2\dots n}\left[\begin{array}{l}(n+i)^{n-1}\sin(n+i)\mu + (n-i)^{n-1}\sin(n-i)\mu) \\ -N_1(n-2+i)^{n-1}\sin(n-2+i)\mu - N_1(n-2-i)^{n-1}\sin(n-2-i)\mu \\ \pm N_r\big((n-2r+i)^{n-1}\sin(n-2r+i)\mu + (n-2r-i)^{n-1}\sin(n-2r-i)\mu\big)\end{array}\right]$$

§ 13. The general term of v (A) (§ 3) being $= +\frac{2}{i}\lambda^i \sin i\epsilon$, we still want the expression of λ^i in a series proceeding according to the powers of e, to obtain which we may use the same method of functions. Let $1+\sqrt{(1-e^2)}$ be called y; then we shall have $\lambda = \frac{e}{y}$ (§ 3), $\frac{1}{y} = \frac{1}{1+\sqrt{(1-e^2)}} = \frac{1-\sqrt{(1-e^2)}}{e^2} = \frac{2-y}{e^2}$, therefore $0 = \frac{e^2}{y} + y - 2$. This equation agrees with (1) (§ 4) $0 = y + x.\varphi(y) - a$, if we suppose $e^2 = x$, $\varphi(y) = \frac{1}{y}$, $a = 2$; and the sought function $\psi(y)$ is $= \frac{1}{y^i}$, which, when found, will give $\lambda^i = e^i\,\psi(y)$. Now if we again, for the sake of brevity, write φ, $\psi\,\varphi'$, ψ', for $\varphi(y)$, $\psi(y)$, etc. we shall have $\frac{d\psi}{dy}$ or $\psi' = -\frac{i}{y^{i+1}} = -i.(\varphi)^{i+1}$; whence the equation (6) (§ 6) will be transformed into

$$\text{(11)}\quad \psi = u + ix.(\phi)^{i+2} - \frac{ix^2}{1.2}\cdot\frac{d.(\phi)^{i+3}}{dy} + \frac{ix^3}{1.2.3}\cdot\frac{dd.(\phi)^{i+4}}{dy^2} - \text{etc.}$$

But ϕ is $= \frac{1}{y}$, $\varphi' = \frac{d\phi}{dy} = -\frac{1}{y^2} = -(\varphi)^2$; therefore

$$\frac{d.(\varphi)^n}{dy} = n(\varphi)^{n-1}.\phi' = -n(\varphi)^{n+1};\ \frac{dd.(\varphi)^n}{dy^2} = -n(n+1).(\phi)^n.\phi' = +n(n+1).(\phi)^{n+2};$$
$$\frac{d^3(\varphi)^n}{dy^3} = n(n+1)(n+2).(\varphi)^{n+1}.\varphi' = -n(n+1)(n+2).(\varphi)^{n+3};\ \text{etc.}$$

All these differentials are comprehended in the form

$$(a)\quad \frac{d^r(\varphi)^n}{dy^r} = \pm\, n(n+1)\dots(n+r-1).(\varphi)^{n+r},$$

the upper or lower sign taking place, according to the number r is even or odd. To demonstrate the general truth of this form, we

need only to take the differential of (a) once more, whence we shall get

$$\frac{d^{r+1}.(\phi)^n}{dy^{r+1}} = \pm n(n+1)\ldots(n+r-1)(n+r).(\varphi)^{n+r-1}.\phi' = \mp n(n+1)\ldots(n+r).(\varphi)^{n+r+1},$$

which is deduced from $r+1$, in the same manner as $d^r.(\varphi)^n$ is deduced from r; whence it follows, that the supposed form (a) is generally true. If in the series (11) we put successively $n=i+3$ and $r=1$, $n=i+4$ and $r=2$, and so on, all its terms will have the sign +, since no differentials but those of an odd degree r are negative: whence the equation (11) becomes

$$\psi = u + ix.(\varphi)^{i+2} + \frac{x^2}{1.2}.i(i+3).(\phi)^{i+4} + \frac{x^3}{1.2.3}.i(i+4)(i+5).(\varphi)^{i+6} + \text{etc.}$$

Substituting in this equation the former values (§ 6)

$u=\psi(a)=\frac{1}{a^i}=\frac{1}{2^i}$, $\varphi=\varphi(a)=\frac{1}{a}=\frac{1}{2}$, $x=e^2$, and $\lambda^i=e^i\,\psi$, we shall obtain

$$(12)\ \lambda^i = \left(\frac{e}{2}\right)^i.\left[1+i\left(\frac{e}{2}\right)^2+\frac{i(i+3)}{1.2}.\left(\frac{e}{2}\right)^4+\ldots+\frac{i(i+k+1)(i+k+2)\ldots(i+2k-1)}{1.2.3\ldots\ldots k}\left(\frac{e}{2}\right)^{2k}\right]$$

§ 14. In order to develop the series (A) (§ 3) as far as the twelfth power of e, we want the values of λ^i and $\sin iu$ as far as the same power, observing, that since $\sin iu$ is multiplied into λ^i, both these quantities need only be developed as far as the power e^{12-i}. Thus, the equation (12) produces the following values:

$$2\lambda = e\left[1+\frac{e^2}{4}+\frac{e^4}{8}+\frac{5e^6}{2^6}+\frac{7e^8}{2^7}+\frac{21.e^{10}}{2^9}\right];$$

$$\frac{2}{2}\lambda^2 = \frac{e^2}{4}\left[1+\frac{e^2}{2}+\frac{5e^4}{2^4}+\frac{7e^6}{2^5}+\frac{21\,e^8}{2^7}+\frac{33.e^{10}}{2^8}\right];$$

$$\frac{2}{3}\lambda^3 = \frac{e^3}{12}\left[1+\frac{3e^2}{4}+\frac{9e^4}{2^4}+\frac{7e^6}{2^4}+\frac{45.e^8}{2^7}\right];$$

$$\frac{2}{4}\lambda^4 = \frac{e^4}{2^5}\left[1+e^2+\frac{7e^4}{2^3}+\frac{3e^6}{2^2}+\frac{3.5.11.e^8}{2^8}\right];$$

$$\frac{2}{5}\lambda^5 = \frac{e^5}{2^4.5}\left[1+\frac{5e^2}{4}+\frac{5e^4}{4}+\frac{3.5^2.e^6}{2^6}\right];\quad \frac{2}{6}\lambda^6 = \frac{e^6}{2^6.3}\left[1+\frac{3e^2}{2}+\frac{27.e^4}{2^4}+\frac{55.e^6}{2^5}\right];$$

$$\frac{2}{7}\lambda^7 = \frac{e^7}{2^6.7}\left[1+\frac{7e^2}{4}+\frac{35.e^4}{2^4}\right];\quad \frac{2}{8}\lambda^8 = \frac{e^8}{2^{10}}\left[1+2e^2+\frac{11.e^4}{4}\right];$$

$$\frac{2}{9}\lambda^9 = \frac{e^9}{2^8.9}\left[1+\frac{9e^2}{4}\right];\quad \frac{2}{10}\lambda^{10} = \frac{e^{10}}{2^{10}.5}\left[1+\frac{5e^2}{2}\right];\quad \frac{2}{11}\lambda^{11} = \frac{e^{11}}{2^{10}.11};\quad \frac{2}{12}\lambda^{12} = \frac{e^{13}}{2^{13}.3}.$$

§ 15. If in the equation (E) (§ 12) we put successively $i=1$, $i=2$, and so on, as far as $i=12$, and at the same time $n=3$, $n=4$, and so on to $n=12-i$, we shall get

$$\sin\epsilon = \sin\mu + \frac{e}{2}\sin 2\mu + \frac{e^2}{2^3}(3\sin 3\mu - \sin\mu) + \frac{e^3}{2.3}(2\sin 4\mu - \sin 2\mu)$$
$$+ \frac{e^4}{2^7.3}(5^3.\sin 5\mu - 3^4.\sin 3\mu + 2\sin\mu) + \frac{e^5}{2^4.3\,5}(3^4.\sin 6\mu - 2^6.\sin 4\mu + 5\sin 2\mu)$$
$$+ \frac{e^6}{2^{10}.3^2.5}(7^5.\sin 7\mu - 5^6.\sin 5\mu + 3^7.\sin 3\mu - 5\sin\mu)$$
$$+ \frac{e^7}{2^4.3^2.5.7}(2^{11}.\sin 8\mu - 3^7.\sin 6\mu + 2^6.7.\sin 4\mu - 7\sin 2\mu)$$
$$+ \frac{e^8}{2^{15}.3^2.5.7}(3^{14}.\sin 9\mu - 7^8.\sin 7\mu + 2^2.5^8.\sin 5\mu - 2^2.3^7.7.\sin 3\mu + 2.7.\sin\mu)$$
$$+ \frac{e^9}{2^8.3^4.5.7}(5^8.\sin 10\mu - 2^{19}.\sin 8\mu + 3^{11}.\sin 6\mu - 2^{12}.3.\sin 4\mu + 2.3.7.\sin 2\mu)$$
$$+ \frac{e^{10}}{2^{18}.3^4.5^2.7}(11^9.\sin 11\mu - 3^{20}.\sin 9\mu + 5.7^{10}.\sin 7\mu - 3.5^{11}.\sin 5\mu + 2.3^{11}.5.\sin 8\mu - 2.3.7\sin.\mu)$$
$$+ \frac{e^{11}}{2^8.3^4.5^2.7.11}(2^9.3^{10}.\sin 12\mu - 5^{11}.\sin 10\mu + 2^{21}.11.\sin 8\mu - 3^{10}.5.11.\sin 6\mu + 2^9.3.5.11.\sin.4\mu - 2.3.11.\sin.2\mu);$$

$$\sin 2\epsilon = \sin 2\mu + e(\sin 3\mu - \sin\mu) + e^2(\sin 4\mu - \sin 2\mu) + \frac{e^3}{2^3.3}(5\ .\sin 5\mu - 3^3.\sin 3\mu + 4\sin\mu)$$
$$+ \frac{e^4}{2^3.3}(3^3.\sin 6\mu - 2^5.\sin 4\mu + 7.\sin 2\mu) + \frac{e^5}{2^7.3.5}(7^4.\sin 7\mu - 5^5.\sin 5\mu + 3^4.11.\sin 3\mu - 3.5.\sin.\mu)$$
$$+ \frac{e^6}{2^3.3^2.5}(2^9.\sin 8\mu - 3^6.\sin 6\mu + 2^8.\sin 4\mu - 13\sin 2\mu)$$
$$+ \frac{e^7}{2^{10}.3^2.5.7}(3^{12}.\sin 9\mu - 7^7.\sin 7\mu + 2.5^6.11.\sin 5\mu - 2.3^7.7.\sin 3\mu + 2^3.7.\sin\mu)$$
$$+ \frac{e^8}{2^7.3^2.5.7}(5^7.\sin 10\mu - 2^{17}.\sin 8\mu + 3^7.29.\sin 6\mu - 2^{13}.\sin 4\mu + 2.7^2.\sin 2\mu)$$
$$+ \frac{e^9}{2^{15}.3^4.5.7}(11^8.\sin 11\mu - 3^{18}.\sin 9\mu + 7^8.37.\sin 7\mu - 3.5^8.31.\sin 5\mu + 2.3^{12}.\sin 3\mu - 2.3.5.7.\sin.\mu)$$
$$+ \frac{e^{10}}{2^7.3^4\,5^2.7}(2^8.3^9.\sin 12\mu - 5^{10}.\sin 10\mu + 2^{18}.23.\sin 8\mu - 3^9.5.13.\sin 6\mu + 2^8.3.5.17.\sin 4\mu - 2.3.31.\sin 2\mu)$$

$$\sin 3\epsilon = \sin 3\mu + \frac{3}{2}e(\sin 4\mu - \sin 2\mu) + \frac{3e^2}{2^3}(5\sin 5\mu - 2.3.\sin 3\mu + \sin\mu)$$
$$+ \frac{3e^3}{4}(3\sin 6\mu - 4\sin 4\mu + \sin 2\mu) + \frac{e^4}{2^7}(7^3.\sin 7\mu - 2^2.5^3.\sin 5\mu + 2.3^4.\sin 3\mu - 3\sin\mu)$$
$$+ \frac{e^5}{2^4.5}(2^8.\sin 8\mu - 3^4.5.\sin 6\mu + 2^5.5.\sin 4\mu - 3^2.\sin 2\mu)$$
$$+ \frac{e^6}{2^{10}.5}(3^9.\sin 9\mu - 2.7^5.\sin 7\mu + 5^6.\sin 5\mu - 3^4.19.\sin 3\mu + 3\sin\mu)$$
$$+ \frac{e^7}{2^5.3.5.7}(5^6.\sin 10\mu - 2^{12}.7.\sin 8\mu + 3^7.7.\sin 6\mu - 2^7.17.\sin 4\mu + 2^2.7.\sin 2\mu)$$
$$+ \frac{e^8}{2^{15}.3.5.7}(11^7.\sin 11\mu - 2^3.3^{14}.\sin 9\mu + 2^2.7^8.\sin 7\mu - 5^8.11.\sin 5\mu + 2.3^7.31.\sin 3\mu - 2^3.7.\sin\mu)$$
$$+ \frac{e^9}{2^8.3^2.5.7}(2^8.3^6.\sin 12\mu - 5^8.\sin 10\mu + 2^{18}.\sin 8\mu - 3^6.83.\sin 6\mu + 2^8 13.\sin 4\mu - 2.5.\sin 2\mu);$$

$$\sin 4\varepsilon=\sin 4\mu+2e(\sin 5\mu-\sin 3\mu)+e^2(3\sin 6\mu-4\sin 4\mu+\sin 2\mu)$$

$$+\frac{e^3}{2^2.3}(7^2.\sin 7\mu-3.5^2.\sin 5\mu+3^3.\sin 3\mu-\sin\mu)+\frac{e^4}{3}(2^4.\sin 8\mu-3^3.\sin 6\mu+2^2.3\sin 4\mu-\sin 2\mu)$$

$$+\frac{e^5}{2^6.3.5}(3^8.\sin 9\mu-5.7^4.\sin 7\mu+2.5^5.\sin 5\mu-2.3^4.5.\sin 3\mu+2.3.\sin\mu)$$

$$+\frac{e^6}{2^3.3^2.5}(5^5.\sin 10\mu-2^{11}.3.\sin 8\mu+3^6.5.\sin 6\mu-2^7.5.\sin 4\mu+2^4.\sin 2\mu)$$

$$+\frac{e^7}{2^9.3^2.5.7}(11^6.\sin 11\mu-3^{12}.7.\sin 9\mu+3.7^7.\sin 7\mu-5^7.7.\sin 5\mu+2^2.3^8.\sin 3\mu-2^2.7.\sin\mu)$$

$$+\frac{e^8}{2^3.3^2.5.7}(2^4.3^7.\sin 12\mu-5^7.\sin 10\mu+2^{13}.7.\sin 8\mu-3^7.7.\sin 6\mu+2^4.71.\sin 4\mu-2^3.\sin 2\mu);$$

$$\sin 5\varepsilon=\sin 5\mu+\frac{5}{2}e(\sin 6\mu-\sin 4\mu)+\frac{5e^2}{2^3}(7\sin 7\mu-10.\sin 5\mu+3.\sin 3\mu)$$

$$+\frac{5e^3}{2^2.3}(2^4.\sin 8\mu-3^3.\sin 6\mu+2^2.3.\sin 4\mu-\sin 2\mu)$$

$$+\frac{5e^4}{2^7.3}(3^6.\sin 9\mu-2^2.7^3.\sin 7\mu+2.3.5^3.\sin 5\mu-2^2.3^2.\sin 3\mu+\sin\mu)$$

$$+\frac{5e^5}{2^4.3}(5^3.\sin 10\mu-2^8.\sin 8\mu+2.3^4.\sin 6\mu-2^5.\sin 4\mu+\sin 2\mu)$$

$$+\frac{e^6}{2^{10}.3^2}(11^5.\sin 11\mu-2.3^{11}.\sin 9\mu+3.5.7^5.\sin 7\mu-2^2.5^6.\sin 5\mu+3^6.5.\sin 3\mu-5\sin\mu)$$

$$+\frac{e^7}{2^5.3^2.7}(2^6.3^6.\sin 12\mu-5^6.7.\sin 10\mu+2^{12}.3.7.\sin 8\mu-3^6.5.7.\sin 6\mu+2^6.5.7.\sin 4\mu-2^2.5.\sin 2\mu);$$

$$\sin 6\varepsilon=\sin 6\mu+3e(\sin 7\mu-\sin 5\mu)+3e^2(2\sin 8\mu-3\sin 6\mu+\sin 4\mu)$$

$$+\frac{3e^3}{2^3}(3^3.\sin 9\mu-7^2.\sin 7\mu+5^2.\sin 5\mu-3\sin 3\mu)$$

$$+\frac{e^4}{2^3}(5^3.\sin 10\mu-2^8.\sin 8\mu+2.3^4.\sin 6\mu-2^5.\sin 4\mu+\sin 2\mu)$$

$$+\frac{e^5}{2^7.5}(11^4.\sin 11\mu-3^8.5.\sin 9\mu+2.5.7^4.\sin 7\mu-2.5^5.\sin 5\mu+3^4.5\sin 3\mu-\sin\mu)$$

$$+\frac{e^6}{2^3.5}(2^4.3^4\sin 12\mu-5^5.\sin 10\mu+2^9.5.\sin 8\mu-2.3^4.5.\sin 6\mu+2^4.5.\sin 4\mu-\sin 2\mu);$$

$$\sin 7\varepsilon=\sin 7\mu+\frac{7}{2}e(\sin 8\mu-\sin 6\mu)+\frac{7e^2}{2^3}(3^2.\sin 9\mu-2.7.\sin 7\mu+5\sin 5\mu)$$

$$+\frac{7e^3}{2^2.3}(5^2.\sin 10\mu-2^4.3.\sin 8\mu+3^3.\sin 6\mu-2^2.\sin 4\mu)$$

$$+\frac{7e^4}{2^7.3}(11^3.\sin 11\mu-2^2.3^6.\sin 9\mu+2.3.7^3.\sin 7\mu-2^2.5^3.\sin 5\mu+3^3.\sin 3\mu)$$

$$+\frac{7e^5}{2^4.3.5}(2^4.3^4.\sin 12\mu-5^5.\sin 10\mu+2^9.5.\sin 8\mu-2.3^4.5.\sin 6\mu+2^4.5.\sin 4\mu-\sin 2\mu):$$

$$\sin 8\epsilon=\sin 8\mu+4e(\sin 9\mu-\sin 7\mu)+2e^2.(5\sin 10\mu-2^3.\sin 8\mu+3\sin 6\mu)$$

$$+\frac{e^3}{2.3}11^2.\sin 11\mu-3^5.\sin 9\mu+3.7^2.\sin 7\mu-5^2.\sin 5\mu)$$

$$+\frac{2}{3}e^4(2.3^3.\sin 12\mu-5^3.\sin 10\mu+2^6.3.\sin 8\mu-3^3.\sin 6\mu+2\sin 4\mu);$$

$$\sin 9\epsilon=\sin 9\mu+\frac{9}{2}e(\sin 10\mu-\sin 8\mu)+\frac{9}{2^3}e^2(11\sin 11\mu-2.9.\sin 9\mu+7.\sin 7\mu)$$

$$+\frac{9}{4}e^3(2^2 3.\sin 12\mu-5^2.\sin 10\mu+2^4.\sin 8\mu-3.\sin 6\mu);$$

$$\sin 10\epsilon=\sin 10\mu+5e(\sin 11\mu-\sin 9\mu)+5\epsilon^2(3\sin 12\mu-5\sin 10\mu+2\sin 8\mu);$$

$$\sin 11\epsilon=\sin 11\mu+\frac{11}{2}e(\sin 12\mu-\sin 10\mu);\qquad \sin 12\epsilon=\sin 12\mu.$$

§ 16. These equations contain every thing necessary for developing v as far as the 12th power of e: for, by multiplying each sine in § 15 by the correspondent power of λ in § 14, and adding these products to ϵ (§ 10), we shall get the required series (A). All this will appear evident by an example.

Let the Coefficient of $\sin \mu$ be sought: then, whatever is multiplied by $\sin \mu$, in ϵ, in $2\lambda \sin \epsilon$, in $\frac{3}{2}\lambda^2 \sin 2\epsilon$, etc. may be united into one sum, which sum will be the required Coefficient of $\sin \mu$.

Hence we get from ϵ, $e-\frac{e^3}{8}+\frac{e^5}{2^6.3}-\frac{e^7}{2^{10}.3^2}+\frac{e^9}{2^{14}.3^2.5}-\frac{e^{11}}{2^{17}.3^3.5^2}$;

from $2\lambda \sin \epsilon$, $e(1+\frac{e^2}{4}+\frac{e^4}{8}+\frac{5e^6}{2^6}+\frac{7e^8}{2^7}+\frac{21.e^{10}}{2^9})$

$$-\frac{e^3}{2^3}(1+\frac{e^2}{4}+\frac{e^4}{8}+\frac{5e^6}{2^6}+\frac{7e^8}{2^7})+\frac{e^5}{2^6.3}(1+\frac{e^2}{4}+\frac{e^4}{8}+\frac{5e^6}{2^6})$$

$$-\frac{e^7}{2^{10}.3^2}(1+\frac{e^2}{4}+\frac{e^4}{8})+\frac{e^9}{2^{14}.3^2.5}(1+\frac{e^2}{4})-\frac{e^{11}}{2^{17}.3^3.5^2};$$

from $\frac{2}{2}\lambda^2 \sin 2\epsilon$, $-\frac{e^3}{4}(1+\frac{e^2}{2}+\frac{5e^4}{2^4}+\frac{7e^6}{2^5}+\frac{21e^8}{2^7})$

$$+\frac{e^5}{2^5.3}\left(1+\frac{e^2}{2}+\frac{5e^4}{2^4}+\frac{7e^6}{2^5}\right)-\frac{e^7}{2^9}\left(1+\frac{e^2}{2}+\frac{5e^4}{2^4}\right)$$

$$+\frac{e^9}{2^9.3^2.5}\left(1+\frac{e^2}{2}\right)-\frac{e^{11}}{2^{16}.3^3};$$

from $\frac{2}{3}\lambda^3 \sin 3\varepsilon, +\frac{e^5}{2^5}\left(1+\frac{3e^2}{4}+\frac{9e^4}{2^4}+\frac{7e^6}{2^4}\right)-\frac{e^7}{2^9}\left(1+\frac{3e^2}{4}+\frac{9e^4}{2^4}\right)$

$$+\frac{e^9}{2^{12}.5}\left(1+\frac{3e^2}{4}\right)-\frac{e^{11}}{2^{15}.3^2.5};$$

from $\frac{2}{4}\lambda^4 \sin 4\varepsilon, -\frac{e^7}{2^7.3}\left(1+e^2+\frac{7e^4}{2^3}\right)+\frac{e^9}{2^{10}.5}(1+e^2)-\frac{e^{11}}{2^{12}.3^2.5}$;

from $\frac{2}{5}\lambda^5 \sin 5\varepsilon, +\frac{e^9}{2^{11}.3}\left(1+\frac{5e^2}{4}\right)-\frac{e^{11}}{2^{14}.3^2}$;

and from $\frac{2}{6}\lambda^6 \sin 6\varepsilon, \quad -\frac{e^{11}}{2^{13}.3.5}$.

The following sines would give only products of $\sin\mu$ multiplied into powers of e higher than the 12th. Wherefore, these seven partial coefficients being collected, we shall find the whole coefficient of $\sin\mu =$

$$+e(1+1)+e^3\left(-\frac{1}{8}+\frac{1}{4}-\frac{1}{8}-\frac{1}{4}\right)+e^5\left(\frac{1}{2^6.3}+\frac{1}{8}-\frac{1}{2^5}+\frac{1}{2^6.3}-\frac{1}{8}+\frac{1}{2^3.3}+\frac{1}{2^5}\right)$$

$$+e^7\left(-\frac{1}{2^{10}.3^2}+\frac{5}{2^6}-\frac{1}{2^6}+\frac{1}{2^8.3}-\frac{1}{2^{10}.3^2}-\frac{5}{2^6}+\frac{1}{2^4.3}-\frac{1}{2^9}+\frac{3}{2^7}-\frac{1}{2^9}-\frac{1}{2^7.3}\right)$$

$$+e^9\begin{cases}\frac{1}{2^{14}.3^2.5}+\frac{7}{2^7}-\frac{5}{2^9}+\frac{1}{2^9.3}-\frac{1}{2^{12}.3^2}+\frac{1}{2^{14}.3^2.5}-\frac{7}{2^7}+\frac{5}{2^7.3}-\frac{1}{2^{10}}\\ +\frac{1}{2^9.3^2.5}+\frac{9}{2^9}-\frac{3}{2^{11}}+\frac{1}{2^{12}.5}-\frac{1}{2^7.3}+\frac{1}{2^{10}.5}+\frac{1}{2^{11}.3}\end{cases}$$

$$+e^{11}.\begin{cases}-\frac{1}{2^{17}.3^3.5^2}+\frac{21}{2^9}-\frac{7}{2^{10}}+\frac{5}{2^{12}.3}-\frac{1}{2^{13}.3^2}+\frac{1}{2^{16}.3^2.5}-\frac{1}{2^{17}.3^3.5^2}-\frac{21}{2^9}+\frac{7}{2^8.3}-\frac{5}{2^{13}}+\frac{1}{2^{10}.3^2.5}\\ -\frac{1}{2^{16}.3^3}+\frac{7}{2^9}-\frac{9}{2^{13}}+\frac{3}{2^{14}.5}-\frac{1}{2^{15}.3^2.5}-\frac{7}{2^{10}.3}+\frac{1}{2^{10}.5}-\frac{1}{2^{12}.3^2.5}+\frac{5}{2^{11}.3}-\frac{1}{2^{14}.3^2}-\frac{1}{2^{13}.3.5}\end{cases}$$

The reduction of all the fractions, belonging to the same power of e, to the least common denomination, will give the coefficient of

$$\sin\mu = 2e-\frac{e^3}{4}+\frac{5}{2^5.3}e^5+\frac{107}{2^9.3^2}e^7+\frac{6217}{2^{13}.3^2.5}e^9+\frac{565879}{2^{16}.3^3.5^2}e^{11};$$

which is the second term of v (A) (§ 3), the first being $=\mu$.

§ 17. By means of the above formulæ, it is easy to develop the series (A), or the true anomaly v, as far as we please; and the Problem seems to be completely resolved. But the whole operation is, strictly speaking, nothing but an indirect method of approximation; and, as the discovery of the Binomial Theorem would not be complete, if we had not a general formula for each Binomial Coefficient N_r, independent of all others, so Kepler's Problem cannot be said to be completely resolved, unless we have a general formula, which gives immediately, and independently of the preceding or following terms, any term of v. Therefore, knowing that v is a series composed of terms of this form $Ae^a \sin m\mu$, the *direct* solution of our Problem is reduced to the investigation of a general formula, by which the coefficient or multiplicator A may be found immediately, and without having recourse to the above series, ϵ, $\sin i\,\epsilon$, λ^i, whatever may be the given numbers a and m, or in other words, to express A by a function of a and m only. Such a general and independent expression of A is particularly useful, when the object is, to verify an isolated term which, for some reason, appears to be doubtful; a case by no means rare, as every one knows, who is acquainted with these calculations. Moreover, it will appear, that the computation by this method is easier than by the common one, and it is not so liable to mistakes in the calculation; it shews also the general law, by which all the terms of v are formed, whereas this law is quite lost in the common method.

§ 18. The Problem, which we have now to resolve, is, whatever may be the numbers a and m, in the term $Ae^a \sin m\mu$, to find a general expression of A. But there is a very essential observation to be made, *viz.* that the numbers a and m are not wholly in-

dependent of each other. The general term of sin $i\epsilon$ (E) (§ 12), neglecting the coefficients by which they are multiplied, has the following form, $e^n \sin(n\pm i-2r)\mu$; and when multiplied by λ^i (12) (§ 13), it assumes the forms $e^{n+i}(1+..e^2+..e^4+\text{etc.})(\sin(n\pm i)\mu+\sin(n\pm i-2r)\mu+\text{etc.})$, or $e^a(1+e^2+e^4+...)(\sin a\mu+\sin(a-2)\mu+...)$, which is also the form of ϵ (D) (§ 9). Therefore it is evident, that in every term $e^a \sin m\mu$ of the series (A), we shall have $a=m$, or $a=m+2$, or in general $a=m+2s$, in other words, a and m must be either both even or both odd, and m can never be greater than a: therefore I shall hereafter suppose $m=a-2s$, or $\frac{a-m}{2}=s$, the letter s denoting any affirmative number, not excluding 0. If we were to give to m a value not falling under the form $a-2s$, the term $Ae^a \sin m\mu$ would be impossible, or $A=0$.

§ 19. Since v is in general $=\epsilon+\frac{2}{i}\lambda^i \sin i\epsilon$ (A) (§ 3), the quantity A will depend in part upon ϵ, and in part upon $\sin i\epsilon$. The former part, which we shall call $A^{(0)}$, must be deduced from the general term of ϵ (D) (§ 9) $=\pm\frac{N_r}{2^{n-1}}\cdot\frac{e^n}{1.2..n}\cdot(n-2r)^{n-1}\sin(n-2r)\mu$, which will agree with the proposed term $Ae^a \sin m\mu$, if we make $n=a$, and $n-2r=m$, or $r=\frac{a-m}{2}=s$ (§ 18): whence we get $A^{(0)}=\pm\frac{N_s}{1.2..a}\left(\frac{m}{2}\right)^{n-1}$; N denoting the general coefficient of a binomial raised to the power n (§ 8). In the present case, n is equal to a, therefore, putting A for the general coefficient of a binomial raised to the power a, so that $A_0=1$, $A_1=a$, $A_2=\frac{a(a-1)}{1.\ 2}$, and $A_s=\frac{a(a-1)\,.....\,(a-s+1)}{1.\ 2\,......\,s}$, we shall get (*b*) $A^{(0)}=\pm\frac{A_s}{1.2....a}\left(\frac{m}{2}\right)^{a-1}$

If, for instance, we seek the coefficient of $e^{11} \sin \mu$, arising from ι, we shall have $a = 11, m = 1, s = 5$, wherefore

$$A^{(\iota)} = -\frac{11.10.9.8.7}{1.\ 2.\ 3.4.5} \cdot \frac{1}{2^{10}.12....11} = -\frac{1}{2^{17}.3^3.5^2}, \text{ as above } (\S\ 16).$$

§ 20. The general term of $\sin i\iota$ (E) (§ 12) is $= \sin i\mu \pm \frac{i}{2^n}\cdot$

$$\frac{N_r\, e^n}{1.2.3...n}[(n-2r+i)^{n-1} \sin (n-2r+i)\, \mu + (n-2r-i)^{n-1} \sin (n-2r-i)\, \mu] = E^{(i)},$$

in which we must observe, that $2r$, can never become greater than n, therefore the first argument, $n-2r+i$, is always affirmative, whereas the other, $n-2r-i$, will often be negative, in which case the product $(n-2r-i)^{n-1} \sin (n-2r-i)\, \mu$ will be affirmative or negative, according as the number n is even or odd, because the sine of a negative angle is always negative. Let the coefficient $\frac{i(i+k+1)\,(i+k+2)\,......\,(i+2k-1)}{1.\quad 2.\quad 3.\,.\,.\,.\,.\,.\,.\,.\,k}$ be called J_k, in which we must observe, that J_1 is equal to i, and J_0 equal to 1 (12) (§ 13): then, the general term of λ^i will be

$$= + J_k\left(\frac{e}{2}\right)^{i+2k} = L^{(i)}. \quad \text{Therefore,}$$

$$\frac{2}{i}\lambda^i \sin i\iota = \frac{2}{i} L^{(i)}.\, E^{(i)}. = \frac{2}{i} J_k\left(\frac{e}{2}\right)^{i+2k} \sin i\,\mu$$

$$\pm \frac{2\,N_r}{1.2...n} J_k\left(\frac{e}{2}\right)^{i+2k+n} [(n-2r+i)^{n-1}\sin(n-2r+i)\mu + (n-2r-i)^{n-1}\sin(n-2r-i)\mu];$$

whence the coefficient of $e^a \sin m\mu$ is to be deduced. But it is evident, that the first term, $\sin i\mu$, is applicable only to the particular case where $i = m = a - 2s$; whence it follows, that $i + 2k = m + 2k = a$, and consequently $k = s$, whence the first term, which we shall call $A^{(m)}$, becomes $= \frac{J_s}{2^{a-1}.m}$, and the coefficient

$$J_s = \frac{m(m+s+1)\,(m+s+2)\,....\,(m+2s-1)}{1.\quad 2.\quad 3.\quad .\ .\ .\ .\ .\quad s} = M_s, \text{ therefore the first}$$

term is

(c) $A^{(m)} = + \frac{M_r}{2^{n-1}.m}$.

§ 21. The remaining part

$$\pm \frac{2\,N_r}{1.2\ldots n}.\,J_k\left(\frac{e}{2}\right)^{i+2k+n}.\left[(n-2r+i)^{n-1}\sin(n-2r+i)\mu+(n-2r-i)^{n-1}\sin(n-2r-i)\mu\right]$$

can be made to agree with the proposed term $e^a \sin m\,\mu$, by three different suppositions

1) $n-2r+i=m$, 2) $n-2r-i=m$, 3) $n-2r-i=-m$,

whence we get

1) $2r=n+i-m$, 2) $2r=n-i-m$, 3) $2r=n-i+m$;

of which, however, no more than two values of r can take place at the same time, whatever may be the number i. For, i is either equal to m, or less, or greater than m. In the first case, 1) and 3) give the same value $r=\frac{n}{2}$, the other being $r=\frac{n}{2}-m$. In the second case, 3) is impossible, because $2r$ can never be greater than n (§ 20); wherefore, there remains only $r=\frac{n+i-m}{2}$ and $r=\frac{n-i-m}{2}$. In the third case, 1) is impossible, for the same reason, and we have only $r=\frac{n-i-m}{2}$ and $r=\frac{n-i+m}{2}$. The first case, $r=\frac{n}{2}$ and $r=\frac{n}{2}-m$, is comprehended in the second case, where $r=\frac{n+i-m}{2}$ and $r=\frac{n-i-m}{2}$, if i becomes equal to m. Thus, we have only the three following values of r,

1) $r=\frac{n+i-m}{2}$, 2) $r=\frac{n-i-m}{2}$, 3) $r=\frac{n-i+m}{2}$;

the last of which gives $n-2r-i=-m$, whence we get

$$(n-2r-i)^{n-1}\sin(n-2r-i)\,\mu=(-m)^{n-1}\sin(-m\,\mu)=$$
$$-(-m)^{n-1}\sin m\,\mu=-m^{n-1}(-1)^{n-1}\sin m\,\mu=+m^{n-1}(-1)^n\sin m\,\mu.$$

§ 22. We have yet to determine the number k. If we call $A^{(i)}$ the sought coefficient of the proposed term $e^a \sin m\mu$, we shall have the equation (§ 20)

$$\pm \frac{2N_r}{1.2...n} . J_k \left(\frac{e}{2}\right)^{i+2k+n} . [(n-2r+i)^{n-1} \sin(n-2r+i)\mu + (n-2r-i)^{n-1} \sin(n-2r-i)\mu]$$

$= A^{(i)} e^n \sin m\mu$; whence it follows, that $i+2k+n$ must be equal to a, or $k = \frac{a-i-n}{2}$. Substituting, then, the three values of r (§ 21), we shall get.

$$(d)\ A^{(i)} = \frac{m^{n-1}}{2^{a-1}.1.2...n} \frac{J_{a-i-n}}{2} [\pm \frac{N_{n+i-m}}{2} \pm \frac{N_{n-i-m}}{2} \pm \frac{N_{n-i+m}}{2} (-1)^n],$$

§ 23. All those quantities, (b) (§ 19), (c) (§ 20), and (d) (§ 22), being collected, the total coefficient of $e^a \sin m\mu$ will be found

$$A^{(0)} + A^{(m)} + A^{(i)} = A = \pm \frac{A_s}{1.2...a}\left(\frac{m}{2}\right)^{a-1} + \frac{M_s}{2^{a-1}.m}$$

$$+ \frac{m^{n-1}}{2^{a-1}.1.2...n} . \frac{J_{a-i-n}}{2} [\pm \frac{N_{n+i-m}}{2} \pm \frac{N_{n-i-m}}{2} \pm \frac{N_{n-i+m}}{2} (-1)^n],$$

in which I shall again observe, that $s = \frac{a-m}{2}$ (§ 18),

$$A_s = \frac{a(a-1)(a-2)\ldots\ldots(a-s+1)}{1.\ 2.\ \ 3.\ \ldots\ldots\ s} \text{ (§ 19,)}$$

$$M_s = \frac{m(m+s+1)(m+s+2)\ldots\ldots(m+2s-1)}{1.\ \ 2.\ \ 3.\ \ldots\ldots\ldots\ s} \text{ (§ 20)},$$

$$J_x = \frac{i(i+x+1)(i+x+2)\ldots\ldots(i+2x-1)}{1.\ \ 2.\ \ 3.\ \ldots\ldots\ldots\ x} \text{ (§ 20)},$$

$$N_x = \frac{n(n-1)(n-2)\ldots\ldots(n-x+1)}{1.\ 2.\ \ 3.\ \ldots\ldots\ldots\ x} \text{ (§ 8)};$$

and that i and n signify any integer affirmative number, whereas the case $i = o$ is contained in the first term A_s, and $n = o$ in the second term M_s. It must, however, be observed, that the value of i and n is limited by this condition, that the exponents at the bottom of the coefficients J and N, *viz*, $a-i-n$, $n+i-m$, $n-i-m$, $n-i+m$, must always be affirmative numbers: for, when any one of these

numbers becomes negative, the corresponding coefficient, J or N, will be $= 0$. Therefore, whatever may be the numbers i and n, there will never be found more than two values of N, sometimes but one, and sometimes none at all; as will appear by the following example.

§ 24. Let the coefficient of $e^{10}\sin 2\mu$ be sought. Then we have

$$a = 10,\ m = 2,\ s = 4,\ \mathrm{A}^{(0)} = +\frac{\mathrm{A}_4}{1.2\ldots10}\ (\S\ 19),\ \mathrm{A}^{m} = \frac{\mathrm{M}_4}{2^{10}}\ (\S\ 20),$$

$$\mathrm{A}^{(i)} = \frac{1}{2^{10-n}.1.2\ldots n}.\mathrm{J}^{\frac{10-i-n}{2}}\left[\pm \mathrm{N}^{\frac{n+i-2}{2}} \pm \mathrm{N}^{\frac{n-i-2}{2}} \pm \mathrm{N}^{\frac{n-i+2}{2}}(-1)^n\right],$$

and the required coefficient $\mathrm{A} = \mathrm{A}^{(0)} + \mathrm{A}^{(m)} + \mathrm{A}^{(i)}$. Let us abridge this notation by writing J for $\mathrm{J}^{\frac{10-i-n}{2}}$, N for $\mathrm{N}^{\frac{n-i-2}{2}}$, N^{1} for $\mathrm{N}^{\frac{n+i-2}{2}}$, and N^{11} for $\mathrm{N}^{\frac{n-i+2}{2}}$, the latter being used only when i is greater than m or 2, in which case N^1 disappears, because $2r$ or $n+i-2$ would be greater than n (§ 23). Therefore,

$$\mathrm{A}^{(i)} = \frac{\mathrm{J}}{2^{10-n}.1.2\ldots n}.\left[\pm \mathrm{N}^1 \pm \mathrm{N} \pm \mathrm{N}^{11}(-1)^n\right].$$

§ 25. The above formulas give $\mathrm{A}^{(0)} = +\frac{10.9.8.7}{1.2.3.4.}.\frac{1}{1.2.3\ldots10} = \ldots\ldots + \frac{1}{2^7.3^3.5}$

$$\mathrm{A}^{(m)} = +\frac{2.7\ 8.9}{1.2.3.4}.\frac{1}{2^{10}} = \ldots\ldots\ldots\ldots\ldots + \frac{21}{2^9}$$

As to the term $\mathrm{A}^{(i)}$, both numbers i and n must be at the same time even or odd, because the exponent of N, $\frac{n \pm i}{2}$, must be an *integer*; moreover, n cannot be greater than $10 - i$, on account of the exponent of J, $\frac{10-i-n}{2}$. Making then,

1) $i = 1,\ n = 1,\ n = 3,\ n = 5,\ n = 7,\ n = 9$;
2) $i = 2,\ n = 2,\ n = 4,\ n = 6,\ n = 8$;
3) $i = 3,\ n = 1,\ n = 3,\ n = 5,\ n = 7$;

4) $i=4,\ n=2,\ n=4,\ n=6$;

5) $i=5,\ n=1,\ n=3,\ n=5$; 6) $i=6,\ n=2,\ n=4$;

the two first cases will give $A^{(i)} = \frac{J(\pm N^{1} \pm N)}{2^{10-n}.1.2...n}$, and the following four $A^{(i)} = \frac{J(\pm N \pm N^{11}(-1)^{n})}{2^{10-n}.1.2.3.\ \ldots\ n}$, because i is greater than m or 2. In the third and fifth cases, n being an odd number, we have $A^{(i)} = \frac{J(\pm N \mp N^{11})}{2^{10-n}.1.2.\ \ldots\ n}$; but in the fourth and fifth cases, where n is even, $A^{(i)}$ is $= \frac{J(\pm N \pm N^{11})}{2^{10-n}.1.2.\ \ldots\ n}$. The coefficient of $e^{10} \sin 2\mu$ terminates with $i=6$, since any value of i, greater than 6, would make $J=0$, or both N and $N^{11}=0$. For, since n cannot be greater than $10-i$, as we have seen, n must needs be less than 4, i being > 6; but then, $n-i-2$ as well as $n-i+2$ become negative, whence $N=0$ and $N^{11}=0$ (§ 23). The account, according to the above formulæ of $A^{(i)}$, stands thus:

if $i=1$ and $n=1$,

$$J=J_4=\frac{1.6.7.8}{1.2.3.4}=2.7,\ N^1=N_0=+1,\ N=0,$$

therefore $A^{(i)}=+\frac{2.7}{2^9}= \ldots\ldots\ldots\ldots\ldots +\frac{7}{2^8}$

if $i=1$ and $n=3$,

$$J=J_3=\frac{1.5.6}{1.2.3}=5\ ;\ N^1=N_1=-n=-3\ ;\ N=N_0=+1$$

$$A^{(i)}=-\frac{5.2}{2^7.1.2.3}= \ldots\ldots\ldots\ldots - \frac{5}{2^7.3}$$

if $i=1$ and $n=5$,

$$J=J_2=\frac{1.4}{1.2}=2\ ;\ N^1=N_2=+\frac{5.4}{1.2}=+10\ ;\ N=N_1=-n=-5\ ;\ A^{(i)}=+\frac{2.5}{2^5.1.2..5}=+\frac{1}{2^7.3}$$

if $i=1$ and $n=7$,

$$J=J_1=i=1\ ;\ N^1=N_3=-\frac{7.6.5}{1.2.3}=-5.7\ ;\ N=N_2=+\frac{7.6}{1.2}=+3.7\ ;\ A^{(i)}=-\frac{2.7}{2^3.1.2..7}=\ldots-\frac{1}{2^6.3^2.5}$$

if $i=1$ and $n=9$.

$$J=J_0=1;\ N^1=N_4=+\frac{9.8.7.6}{1.2.3.4}=+2.7.9;\ N=N_3=-\frac{9.8.7}{1.2.3}=-3.4.7;\ A^{(i)}=+\frac{2.3.7}{2.1.2...9}=\cdots+\frac{1}{2^7.3^3.5}$$

if $i=2$ and $n=2$,

$$J=J_3=\frac{2.6.7}{1.2.3}=2.7;\ N^1=N_1=-n=-2;\ N=0;\ A^{(i)}=-\frac{4.7}{2^8.1.2}=\cdots\cdots-\frac{7}{2^7}$$

if $i=2$ and $n=4$,

$$J=J_2=\frac{2.5}{1.2}=5;\ N^1=N_2=+\frac{4.3}{1.2}=+6;\ N=N_0=+1;\ A^{(i)}=+\frac{5.7}{2^6.2.3.4}=\cdots+\frac{35}{2^9.3}$$

if $i=2$, and $n=6$,

$$J=J_1=i=2;\ N^1=N_3=-\frac{6.5.4}{1.2.3}=-20;\ N=N_1=-n=-6;\ A^{(i)}=-\frac{2.26}{2^4.1.2..6}=\cdots-\frac{13}{2^6.3^2.5}$$

if $i=2$ and $n=8$,

$$J=J_0=1;\ N^1=N_4=+\frac{8.7.6.5}{1.2.3.4}=+2.5.7;\ N=N_2=+\frac{8.7}{1.2}=+2.2.7;\ A^{(i)}=+\frac{2.7.7}{2^2.1.2..8}=+\frac{7}{2^8.3^2.5}$$

if $i=3$ and $n=1$,

$$J=J_3=\frac{3.7.8}{1.2.3}=4.7;\ N=0;\ N^{11}=N_0=+1;\ A^{(i)}=-\frac{4.7}{2^9}=\cdots\cdots\cdots-\frac{7}{2^7}$$

if $i=3$ and $n=3$,

$$J=J_2=\frac{3.6}{1.2}=3.3;\ N=0;\ N^{11}=N_1=-n=-3,\ A^{(i)}=+\frac{3^3}{2^7.2.3}=\cdots\cdots+\frac{9}{2^8}$$

if $i=3$ and $n=5$,

$$J=J_1=i=3;\ N=N_0=+1;\ N^{11}=N_2=+\frac{5.4}{1.2}=+10;\ A^{(i)}=-\frac{3.9}{2^5.1.2..5}=\cdots-\frac{9}{2^8.5}$$

if $i=3$ and $n=7$,

$$J=J_0=1;\ N=N_1=-n=-7;\ N^{11}=N_3=-\frac{7.6.5}{1.2.3}=-5.7;\ A^{(i)}=+\frac{4.7}{2^3.1.2..7}=\cdots+\frac{1}{2^5.3^2.5}$$

if $i=4$ and $n=2$,

$$J=J_2=\frac{4.7}{1.2}=2.7;\ N=0;\ N^{11}=N_0=+1;\ A^{(i)}=+\frac{2.7}{2^8.1.2}=\cdots\cdots+\frac{7}{2^8}$$

if $i=4$ and $n=4$,

$$J=J_1=i=4;\ N=0;\ N^{11}=N_1=-n=-4;\ A^{(i)}=-\frac{4.4}{2^6.2.3.4}=\cdots\cdots-\frac{1}{2^5.3}$$

if $i=4$ and $n=6$,

$$J=J_0=1;\ N=N_0=+1;\ N^{11}=N_2=+\frac{6.5}{1.2}=+15;\ A^{(i)}=+\frac{16}{2^4.1.2..6}=\cdots+\frac{1}{2^4.3^2.5}$$

if $i=5$ and $n=1$,

$N=0$ and $N^{11}=0$, therefore $A^{(i)}=0$;

if $i=5$ and $n=3$,

$J=J_1=i=5$; $N=0$; $N^{11}=N_0=+1$; $A^{(i)}=-\frac{5}{2^7.1.2.3}=\ldots\ldots-\frac{5}{2^8.3}$

if $i=5$ and $n=5$,

$J=J_0=1$; $N=0$; $N^{11}=N_1=-n=-5$; $A^{(i)}=+\frac{5}{2^4.1.2..5}=\ldots\ldots+\frac{1}{2^8.3}$

if $i=6$ and $n=2$,

$N=0$ and $N^{11}=0$, wherefore $A^{(i)}=0$;

if $i=6$ and $n=4$,

$J=J_0=1$; $N=0$; $N^{11}=N_0=+1$; $A^{(i)}=+\frac{1}{2^6.2.3.4}=\ldots\ldots+\frac{1}{2^9.3}$

§ 26. Collecting all the above fractions (§ 25) into one sum, we shall observe the whole coefficient of $e^{10}\sin 2\mu=$

$$+\frac{2}{2^7.3^3.5}+\frac{11}{2^9}-\frac{2}{2^8.3}-\frac{25}{2^8.3^2.5}-\frac{9}{2^8.5}=-\frac{71}{2^8.3^3.5}+\frac{91}{2^9.3.5}=-\frac{142}{2^9.3^3.5}+\frac{819}{2^9.3^3.5}=+\frac{677}{2^9.3^3.5}$$

§ 27. We have yet to find the development of the *radius vector* z, which being given by the equation III, (§ 2) $z=1-e\cos\epsilon$, this development will be obtained by the same method as above, if we substitute in the equation (6) (§ 6), $\psi(y)=\cos\epsilon,=\cos y$. Hence, $\psi'=\frac{d\psi}{dy}=-\sin y$, which being substituted in the equation (6), gives

$$\cos\epsilon=u+x.\varphi.\sin y-\frac{x2}{1.2}.\frac{d.\sin y.(\varphi)^2}{dy}+\text{etc.}$$

in which we must put (§ 7) $x=-e$, $y=\mu$, $u=\cos\mu$, $\varphi=\sin\mu$; whence we get

$$\text{(F)}\ \cos\epsilon,=\cos\mu-e\sin^2\mu-\frac{e^2}{1.2}.\frac{d.\sin^3\mu}{d\mu}-\ldots.-\frac{e^{n-1}}{1.2.3..(n-1)}.\frac{d^{n-2}.\sin^n\mu}{d\mu^{n-2}}.$$

§ 28. In order to find the differential, $d^{n-2}.(\sin\mu)^n$, the differential of the first of the series (7) (§ 8) is to be taken twice, the second four times or not at all, the third three times, and the fourth once, which produces for each of the four series, the same equation

$$2^{n-1}.\frac{d^{n-2}.\sin^n\mu}{d\mu^{n-2}} = -n^{n-2}\cos n\,\mu + N_1(n-2)^{n-2}\cos(n-2)\,\mu - \ldots.$$
$$\mp N_r(n-2r)^{n-2}\cos(n-2r)\,\mu,$$

in which r must always be taken less than $\frac{n}{2}$. Hence the equation (F) becomes

$$\cos\epsilon = \cos\mu + \frac{e}{2}(\cos 2\,\mu - 1) + \frac{1}{2^2}.\frac{e^2}{1.2}(3\cos 3\,\mu - 3\cos\mu) + \ldots\ldots$$
$$+\frac{1}{2^{n-1}}.\frac{e^{n-1}}{1.2\ldots(n-1)}\left[\begin{array}{l} n^{n-2}\cos n\,\mu - N_1(n-2)^{n-2}\cos(n-2)\,\mu + \ldots. \\ \pm N_r(n-2r)^{n-2}\cos(n-2r)\,\mu \end{array}\right.$$

§ 29. This value, being substituted in the equation $z = 1 - e\cos\epsilon$, gives

$$(G)\quad z = 1 - e\cos\mu - \frac{e^2}{2}(\cos 2\,\mu - 1) - \frac{1}{2^2}.\frac{e^3}{1.2}(3\cos 3\,\mu - 3\cos\mu) - \ldots.$$
$$-\frac{1}{2^{n-1}}.\frac{e^n}{1.2\ldots(n-1)}\left[\begin{array}{l} n^{n-2}\cos n\,\mu - N_1(n-2)^{n-2}\cos(n-2)\,\mu + \ldots\ldots \\ \pm N_r(n-2r)^{n-2}\cos(n-2r)\,\mu \end{array}\right.$$

§ 30. The development of this formula as far as the twelfth power of e, gives

$$z = 1 - e\cos\mu - \frac{e2}{2}(\cos 2\mu - 1) - \frac{3e^3}{8}(\cos 3\mu - \cos\mu) - \frac{e^4}{3}(\cos 4\mu - \cos 2\mu)$$
$$-\frac{5e^5}{2^7.3}(5^2.\cos 5\mu - 3^3.\cos 3\mu + 2\cos\mu) - \frac{e^6}{2^4.5}\ 3^3.\cos 6\mu - 2^5.\cos 4\mu + 5\cos 2\mu)$$
$$-\frac{7e^7}{2^{10}.3^2.5}(7^4.\cos 7\mu - 5^5.\cos 5\mu + 3^6.\cos 3\mu - 5\cos\mu)$$
$$-\frac{e^8}{2^2.3^2.5.7}(2^9.\cos 8\mu - 3^6.\cos 6\mu + 2^5.7\cos 4\mu - 7\cos 2\mu)$$
$$-\frac{e^9}{2^{15}.5.7}(3^{12}.\cos 9\mu - 7^7.\cos 7\mu + 2^2.5^7.\cos 5\mu - 2^2\ 3^6.7.\cos 3\mu + 2.7.\cos\mu)$$
$$-\frac{e^{10}}{2^8.3^4.7}(5^7.\cos 10\mu - 2^{17}.\cos 8\mu + 3^{10}.\cos 6\mu - 2^{11}.\ 3.\cos 4\mu + 2.3.7.\cos 2\mu)$$
$$-\frac{11e^{11}}{2^{18}.3^4.5^2.7}(11^8.\cos 11\mu - 3^{18}.\cos 9\mu + 5.7^9.\cos 7\mu - 3.5^{10}.\cos 5\mu + 2.3^{10}.5.\cos 3\mu - 2.3.7.\cos\mu)$$
$$-\frac{e^{12}}{2^7.3^3.5^2.7.11}(2^8.3^9.\cos 12\mu - 5^{10}.\cos 10\mu + 2^{19}.11.\cos 8\mu - 3^9.5.11.\cos 6\mu + 2^8.3.5.11.\cos 4\mu - 2.3.11.\cos 2\mu).$$

§ 31. Nothing now remains but to apply our second or direct method to this series, the general term of which is $Ae^a \cos m\mu$ (§ 29), a being always $=m+2s$. The problem consists in finding a general expression of A, a and m being given; which may be performed, by the method above explained, without the least difficulty. The general term of z (G) (§ 29), being compared with the proposed term, gives the following equation,

$$\mp \frac{N_r}{2^{n-1}} \cdot \frac{e^2}{1.2...(n-1)} (n-2r)^{n-2} \cos (n-2r)\mu = Ae^a \cos m\mu,$$

whence we get $n=a$, $n-2r=m$ or $r=\frac{a-m}{2}=s$. By substituting $r=s$, N_r is changed into N_s, and by substituting $n=a$, N_s becomes $=\frac{a(a-1)(a-2)\,....\,(a-s+1)}{1.\ 2.\ \ 3.\ \ ......\ s} = A_s$ (§ 19), whence we get the coefficient of $e^a \cos m\mu$.

$$A = \mp \frac{A_s \cdot m^{a-2}}{2^{a-1}.1.2...(a-1)};$$

the upper or the lower sign taking place, according as $s=\frac{a-m}{2}$ is even or odd.

§ 32. Let, for instance, the coefficient A of $e^7 \sin 3\mu$ be sought: then, $a=7$, $m=3$, $s=2$, $A_s=A_2=\frac{7.6}{1.2}=3.7$, and $A=-\frac{3.7.3^5}{2^6.1.2...6}=-\frac{3^4.7}{2^{10}.5}$. Let the term $e^{10} \cos 10\mu$ be sought: then, $a=m=10$, $s=0$, $A_s=A_0=1$, and $A=-\frac{10^8}{2^9.1.2..9}=-\frac{5^7}{2^8.3^4.7}$. If $Ae^{11} \cos \mu$ be sought, we shall have $a=11$, $m=1$, $s=5$, $A_s=A_5=\frac{11.10.9.8.7}{1.2.3.4.5}=2.3.7.11$, and $A=+\frac{2.3.7.11}{2^{10}.1.2..10}=+\frac{11}{2^{17}.3^3.5^2}$. If $Ae^5 \cos 5\mu$ is required, we shall have $a=m=5$, $s=0$, $A_s=1$, and $A=-\frac{5^3}{2^4.1.2.3.4}=-\frac{5^3}{2^7.3}$; all which exactly agrees with § 30.

By this method, we can, without the least difficulty calculate z and v to as great a degree of accuracy as we please; and the advantage of this method, especially with regard to the *radius vector*, seems to be evident.

II.

ON A MISTAKE WHICH EXISTS IN THE SOLAR TABLES OF MAYER, LA LANDE AND ZACH.

BY NATHANIEL BOWDITCH, LL. D.

THE attraction of Jupiter produces an equation in the expression of the Sun's distance from the Earth, and a Table is given for its computation by Mayer, in page 25 of the collection published in England in the year 1770 by the Commissioners of Longitude, republished by La Lande in his Astronomy, and by Zach, in his *Tabulæ Mot. Sol.* &c. *Goth.* 1792, &c. but it is rather remarkable, that ever since this Table was first published, which is about fifty years, an error of six signs has always existed in the argument by which the correction is found, so that when the equation is really *subtractive*, it will frequently be found by the Table to be *additive*, and the contrary. This error probably arose from using the longitude of the *Sun*, instead of that of the *Earth*, in finding the angle of commutation t, which is the argument of that equation.

If we retain only the two greatest terms of the correction of the earth's radius vector depending on Jupiter's attraction, given by La Place in page 105, vol. 3 of his "*Mécanique Céleste*," and put for brevity $n'''' t - n'' t + \epsilon'''' - \epsilon'' = t$, they will become

$$+0.0000159384. \cos t - 0.0000090986. \cos. 2t$$

and as the mean distance of the earth from the sun is put = 1, the two preceding terms will represent the equations of the hyperbolic logarithm of the radius vector. Multiplying this by 0.434 to reduce to common logarithms and taking them to six places of decimals they become nearly

$$+ 7. \cos t - 4. \cos 2 t$$

which is the same formula as is given by La Lande in § 3657, of the third edition of his Astronomy.

When t=0, this equation becomes + 3, representing the correction when Jupiter is in *opposition* to the Sun, which, by the Nautical Almanac or La Lande's tables, was the case about the middle of January 1801, at which time the argument of this table was nearly 500, and the tabular correction — 11, instead of + 3. To correct this mistake we must increase the arguments of this Table of Mayer, La Lande and Zach, by 6 signs or 500 parts.

In *De Lambre's* Solar Tables, published in 1806, the form of the Table is wholly altered, the method of entry by a double argument being used; and by thus taking a different path the error is avoided without noticing that it really does exist in the other works.

III.

On the calculation of the oblateness of the earth, by means of the observed lengths of a pendulum in different latitudes, according to the method given by La Place in the second volume of his "Mécanique Céleste," with remarks on other parts of the same work, relating to the figure of the earth.

BY NATHANIEL BOWDITCH, LL. D.

UPON looking over Dr. Rees' Cyclopedia, under the article *Earth*, I found he had inserted the elegant method of computing the oblateness of the Earth, or the ratio between the polar and equatorial diameters, by means of the observed lengths of a pendulum vibrating in a second of time in different latitudes, as it was published by La Place in the second volume of his immortal work the "*Mécanique Céleste*;" but he has allowed the application of the formulas to numbers to remain nearly as in the original work,* and has moreover committed some mistakes of his own, so that the article, as it now stands, is quite imperfect; and as this Cyclopedia has an extensive circulation in our country, it seems to be proper to notice these errors, in order that a currency may not be given to inaccurate ideas on the subject. It may also be mentioned as an additional reason for noticing them, that by correcting the

* In this work there is a mistake which was alluded to in a note to my paper on the total eclipse of 1806, published in the Memoirs of the Academy, in the year 1809, vol. 3, p. 21.

calculation we obtain for the oblateness of the earth, a result much more conformable to those deduced from other methods; and on this account I have thought it would not be unacceptable to the Academy to have these mistakes corrected, and the sources of them pointed out. This is done in the *first* section of the present paper. In the *second* section I have simplified one of La Place's formulas relative to the figure of the earth. In the *third* section I have corrected the expressions of the length of a degree, and also the azimuths given by him in § 38, Book III, of his "*Mécanique Céleste*," (in the hypothesis that the earth is not a spheroid of revolution) for the mistakes arising from the neglect of one of the terms in the expression of the radius of the earth, which produces a considerable effect in the value of one of the formulas.

SECTION FIRST.

There are *four* methods generally used for the purpose of computing the oblateness of the earth, supposing it to be an ellipsoid of revolution. *First.* By comparing the observed lengths of two consecutive degrees of the meridian. *Second.* By comparing the lengths of two degrees of the meridian measured in very different latitudes. *Third.* By means of the observed variations in the lengths of pendulums vibrating in a second of time in different latitudes. *Fourth.* By means of two equations in the moon's motion (the one in longitude the other in latitude) depending on the oblateness of the earth.

The *first* method is liable to much uncertainty. For the greatest difference between the lengths of two consecutive degrees, being only 9 or 10 fathoms, the least error in the lengths of the lines, in the observed angles, or in the altitudes of the heavenly bodies by which the length of the celestial one is determined would produce a great error in the computed oblateness. This

was the case with the first observations made in France, by Picard, Cassini, &c. for the purpose of determining the form of the earth. The errors of the observations affected the result so much that it was supposed by many Mathematicians that its figure was prolate, or lengthened in the direction of the polar axis. Even the late very accurate measures made in France by Messrs. Delambre and Mechain, and in England by General Roy, make the oblateness of that portion of the earth nearly double what its general value is found to be by more distant observations. The greater part of this difference no doubt arises from a real irregularity in the figures of the meridians of the earth; but the method of computation itself labours under a similar defect to that which exists in finding the distance of any terrestrial object by means of its azimuths observed from the extremities of a base line, whose length is very small in comparison with the observed distance of the object. The *second method* of determining the earth's figure by means of distant observations is much more accurate than the preceding, but the various errors of the observations, and the irregularities of the surface of the earth, have a very perceptible effect on the oblateness computed by this method. These irregularities ought not to be so sensible in the results of the *third method* by means of the observed lengths of pendulums, as La Place has proved in Book II, § 33, of his "*Mécanique Céleste*," and with respect to the *fourth method*, it is evident without any calculation that it must be almost wholly independent of this same error. For, on account of the great distance of the moon from the earth, the effect of all the little irregularities of the earth's form, will be hardly perceptible in the attraction on the moon, and the result of the general figure only will prevail. Therefore by using the last method and taking a great number of observations, it would seem

that we ought to obtain a more correct value than by any other way. The next method in point of accuracy would be by the observed lengths of pendulums, and that depending on the actual measures of the degrees of the meridians, which at first sight appears to be the most natural and accurate, would be in fact the least accurate of any of the methods here mentioned.

To obtain the oblateness by means of the lunar equations, the indefatigable Astronomer Burg undertook to compute the coefficients of these equations by means of such of the observations of Maskelyne, as were proper for that purpose, and from these values La Place has computed* the oblateness of the earth. The equation in longitude made it $\frac{1}{305.05}$ and the equation in latitude $\frac{1}{304.6}$, which differ from each other but a very small fraction, and this wonderful agreement of two independent calculations is a great proof in favour of the accuracy of the method, and of the correctness of the result; and if we neglect the decimal parts of these numbers, we may put $\frac{1}{305}$ for the oblateness as determined by this method, and in all probability this is very near to its correct value; we should therefore be led to infer from what has been said, that the oblateness determined by the observations on the pendulums would agree very nearly with this quantity; but according to La Place's calculation this is not the case. For by combining all the observations of the pendulums which he considers as sufficiently correct, he has found the oblateness to be $\frac{1}{335.78}$,† which differs

* In Book VII, § 24, 25.

† This is given in Book III, § 42 of his "*Mécanique Céleste.*" Making use of the observations in Peru, Porto-Bello, Pondicherry, Jamaica, Petit-Goave, Cape of Good Hope, Toulouse, Vienna, Paris, Gotha, London, Petersburgh, Arensgberg, Ponoi, and Lapland.

considerably from the preceding. Onthe other hand by combining the measured degrees of the meridian, in a similar manner, he finds the oblateness to be $\frac{1}{312}$ *; which agrees much better with $\frac{1}{305}$ than the quantity $\frac{1}{335}$ obtained by the pendulums, directly contrary to what it ought to be by the theory, which teaches us that the method by pendulums ought to be more accurate than by the measures of the degrees of the meridian. This difference will be in part rectified if we use the corrected measure of the degree of Lapland as found by Svanberg, but even with this correction the method of pendulums will differ the most from $\frac{1}{305}$ which we have supposed to be the correctest value. This difficulty will, however, be wholly obviated if we correct the calculation for the two numerical mistakes mentioned above, by which means the oblateness will be increased from $\frac{1}{335\cdot78}$ to $\frac{1}{314\cdot75}$ and then the results of the methods by the lunar equations, the pendulums, and the degrees of the meridian will be respectively $\frac{1}{305}$, $\frac{1}{314\cdot7}$ and $\frac{1}{324}$, which are in the natural order indicated by the theory. Having given this sketch of the principles of the computation, I shall now proceed to point out the mistakes alluded to, and in order that we may fully understand the subject, I shall give a brief outline of the method

* This is given in Book III, § 41, of his "*Mécanique Céleste*," using the degrees measured at the Equator, Cape of Good Hope, Pennsylvania, Italy by Boscovich and Le Maire, in France by Delambre and Mechain, in Austria by Liesganig, and in Lapland by Maupertuis. If we use the corrected measure of the degree of Lapland as found by Svanberg and given in Rees' Cyclopedia namely 57196 toises for the latitude 66° 20′ 10″. The oblateness will be decreased from $\frac{1}{312}$ to nearly $\frac{1}{324}$. I took its length of the whole arch measured equal to 1.5°, as given by Dr. Rees, as I had not Svanberg's work to refer to.

used by La Place in computing the most probable oblateness from any number of observations of the lengths of a pendulum, vibrating in a second of time in different latitudes.

The principles he assumes for computing the most probable figure of an elliptical meridian of the earth, is that the sum of all the errors of the observed lengths of the pendulums noticing their signs should be nothing, and that the sum of all these errors taken positively should be a minimum.

Now if $a^{(1)}$, $a^{(2)}$, $a^{(3)}$, &c. be the observed lengths of the pendulums, $p^{(1)}$, $p^{(2)}$, $p^{(3)}$, &c. the squares of the sines of the corresponding latitudes, and $z + py$ the general expression of the length of the pendulums, also $x^{(1)}$, $x^{(2)}$, $x^{(3)}$, &c. the errors of observation, we shall have the following system of equations, in which we shall suppose $p^{(1)}$, $p^{(2)}$, $p^{(3)}$, &c. to be an increasing progression.

$$\begin{array}{l} a^{(1)} - z - p^{(1)}.\, y = x^{(1)} \\ a^{(2)} - z - p^{(2)}.\, y = x^{(2)} \\ a^{(3)} - z - p^{(3)}.\, y = x^{(3)} \\ \;\vdots \quad\; \vdots \quad\; \vdots \quad\; \vdots \\ a^{(n)} - z - p^{(n)}.\, y = x^{(n)} \end{array} \qquad (A)$$

n being the number of observations. If we add all these equations together the sum of the errors on the right hand side of the sum will by hypothesis be equal to nothing; and if we divide this sum by n, we shall obtain an equation of this form

$$A - z - P\, y = o. \qquad (B)$$

which being subtracted from each of the equations (A), we shall get the following system of equations

$$\begin{array}{l} b^{(1)} - q^{(1)}.\, y = x^{(1)} \\ b^{(2)} - q^{(2)}.\, y = x^{(2)} \\ b^{(3)} - q^{(3)}.\, y = x^{(3)} \\ \quad \&c. \end{array} \qquad (O)$$

We must then compute the series of quotients $\frac{b^{(1)}}{q^{(1)}}, \frac{b^{(2)}}{q^{(2)}}, \frac{b^{(3)}}{q^{(3)}}$, &c. and arrange the preceding equations according to the magnitude of these quotients, beginning with the greatest.* The left hand side of these equations arranged in this manner will be composed of a series of terms of the following form

$$\begin{array}{l} h^{(1)}.\, y - c^{(1)} \\ h^{(2)}.\, y - c^{(2)} \\ h^{(3)}.\, y - c^{(3)} \\ \quad \&c. \end{array} \qquad \text{(P)}$$

in which $h^{(1)}, h^{(2)}, h^{(3)}$, &c. are to be supposed positive, by changing the signs of the term when y has a negative coefficient. Then to find the value of y, which will render the sum of all the errors a minimum, we must add the quantities $h^{(1)}, h^{(2)}, h^{(3)}$, &c. until their sum begins to exceed the half sum of all these quantities; and by putting this sum equal to F we must determine r, so that

$$\begin{array}{l} h^{(1)} + h^{(2)} + h^{(3)} \ldots\ldots + h^{(r)} > \tfrac{1}{2}\,\mathrm{F}, \\ h^{(1)} + h^{(2)} + h^{(3)} \ldots\ldots\ h^{(r-1)} < \tfrac{1}{2}\,\mathrm{F}. \end{array} \qquad \text{(F)}$$

Then put $y = \frac{c^{(r)}}{h^{(r)}}$, and by substituting this in the expression 0.00865 $-y$, we shall obtain the ellipticity of the earth which will render the sum of the errors $x^{(1)}, x^{(2)}$, &c. taken positively a *minimum*, as La Place has proved in Book III, § 40—42 of his *Mécanique Céleste.*

La Place has applied the method to the observations made in the places mentioned in the note, page 33, and his system of equa-

* In finding and arranging these quotients we must notice their signs, and if any of them are negative, they must be considered as less than the positive values, so that $1 > -2$, and $-2 > -4$, &c. This remark is made to prevent the mistakes we might fall into by neglecting the signs according to the directions of the writer of the article of the Cyclopedia above mentioned.

tions (A″) corresponding to (A) of the preceding calculation is as follows, the length of the pendulum at Paris being put = 1.

Places	Latitudes		
	D		
Peru	0.00	$0.99669 - z - y \,.\, 0{,}00000 = x^{(1)}$	
Porto-Bello	10.61	$0.99689 - z - y \,.\, 0{,}02752 = x^{(2)}$	
Pondicherry	13.25	$0.99710 - z - y \,.\, 0{,}04270 = x^{(3)}$	
Jamaica	20.00	$0.99745 - z - y \,.\, 0{,}09549 = x^{(4)}$	
Petit-Goave	20.50	$0.99728 - z - y \,.\, 0{,}10016 = x^{(5)}$	
Cape of G. Hope	37.69	$0.99877 - z - y \,.\, 0{,}31142 = x^{(6)}$	
Toulouse	48.44	$0.99950 - z - y \,.\, 0{,}47551 = x^{(7)}$	
Vienna	53.57	$0.99987 - z - y \,.\, 0{,}55596 = x^{(8)}$	(A″)
Paris	54.26	$1.00000 - z - y \,.\, 0{,}56672 = x^{(9)}$	
Gotha	56.63	$1.00006 - z - y \,.\, 0{,}57624 = x^{(10)}$	
London	57.22	$1.00018 - z - y \,.\, 0{,}61244 = x^{(11)}$	
Petersburgh	64.72	$1.00074 - z - y \,.\, 0{,}72307 = x^{(12)}$	
Arensburg	66.60	$1.00101 - z - y \,.\, 0{,}74907 = x^{(13)}$	
Ponoi	74.22	$1.00137 - z - y \,.\, 0{,}84478 = x^{(14)}$	
Lapland	74.53	$1.00148 - z - y \,.\, 0{,}84829 = x^{(15)}$	

The sum of all these equations divided by the number of observations 15, gives the following equation corresponding to (B)

$$0 = 0.99923 - z - y.\ 0{,}43529 \qquad (B'')$$

By subtracting this from each of the equations (A″) we obtain the following system of equation (O″) corresponding to (O) of the preceding method

$$-0{,}00254 + y \,.\, 0{,}43529 = x^{(1)}$$
$$-0{,}00234 + y \,.\, 0{,}40777 = x^{(2)}$$
$$-0{,}00213 + y \,.\, 0{,}39259 = x^{(3)}$$
$$-0{,}00178 + y \,.\, 0{,}33980 = x^{(4)}$$
$$-0{,}00195 + y \,.\, 0{,}33513 = x^{(5)}$$
$$-0{,}00046 + y \,.\, 0{,}12387 = x^{(6)}$$

$$
\begin{array}{l}
0{,}00027 - y \, . \, 0{,}04022 = x^{(7)} \\
0{,}00064 - y \, . \, 0{,}12067 = x^{(8)} \\
0{,}00077 - y \, . \, 0{,}13143 = x^{(9)} \\
0{,}00083 - y \, . \, 0{,}14095 = x^{(10)} \\
0{,}00095 - y \, . \, 0{,}17715 = x^{(11)} \\
0{,}00151 - y \, . \, 0{,}28778 = x^{(12)} \\
0{,}00178 - y \, . \, 0{,}31380 = x^{(13)} \\
0{,}00214 - y \, . \, 0{,}40949 = x^{(14)} \\
0{,}00225 - y \, . \, 0{,}41300 = x^{(15)}
\end{array}
\qquad (O'')
$$

By comparing these with the equations (O) we get $b^{(1)} = -0{,}00254$, $b^{(2)} = -0{,}00234$, $b^{(3)} = -0{,}00213$, &c.; $q^{(1)} = -0{,}43529$, $q^{(2)} = -0{,}40777$, $q^{(3)} = -0{,}39259$, &c. Hence $\frac{b^{(1)}}{q^{(1)}} = 0{,}0058352$, $\frac{b^{(2)}}{q^{(2)}} = 0{,}0057385$, &c.; and if we arrange the equations (O″) according to the order of these quotients $\frac{b^{(1)}}{q^{(1)}}, \frac{b^{(2)}}{q^{(2)}}$, &c. beginning with the greatest, as in the following system (P′) we shall have

$$
\begin{array}{lcl}
\frac{b^{(7)}}{q^{(7)}} = 0{,}0067131 & & y \, . \, 0{,}04022 - 0{,}00027 = - x^{(7)} \\
\frac{b^{(10)}}{q^{(10)}} = 0{,}0058886 & & y \, . \, 0{,}14095 - 0{,}00083 = - x^{(10)} \\
\frac{b^{(9)}}{q^{(9)}} = 0{,}0058586 & & y \, . \, 0{,}13143 - 0{,}00077 = - x^{(9)} \\
\frac{b^{(1)}}{q^{(1)}} = 0{,}0058352 & & y \, . \, 0{,}43529 - 0{,}00254 = x^{(1)} \\
\frac{b^{(5)}}{q^{(5)}} = 0{,}0058186 & & y \, . \, 0{,}33513 - 0{,}00195 = x^{(5)} \\
\frac{b^{(2)}}{q^{(2)}} = 0{,}0057385 & & y \, . \, 0{,}40777 - 0{,}00234 = x^{(2)} \\
\frac{b^{(13)}}{q^{(13)}} = 0{,}0056724 & (P') & y \, . \, 0{,}31380 - 0{,}00178 = - x^{(13)} \quad (P'') \\
\frac{b^{(15)}}{q^{(15)}} = 0{,}0054479 & & y \, . \, 0{,}41300 - 0{,}00225 = - x^{(15)} \\
\frac{b^{(3)}}{q^{(3)}} = 0{,}0054255 & & y \, . \, 0{,}39259 - 0{,}00213 = x^{(3)}
\end{array}
$$

$$\frac{b^{(11)}}{q^{(11)}} = 0{,}0053627 \qquad y\,.\,0{,}17715 - 0{,}00095 = -x(11)$$

$$\frac{b^{(8)}}{q^{(8)}} = 0{,}0053037 \qquad y\,.\,0{,}12067 - 0{,}00064 = -x(8)$$

$$\frac{b^{(12)}}{q^{(12)}} = 0{,}0052471 \qquad y\,.\,0{,}28778 - 0{,}00151 = -x(12)$$

$$\frac{b^{(4)}}{q^{(4)}} = 0{,}0052384 \qquad y\,.\,0{,}33980 - 0{,}00178 = x(4)$$

$$\frac{b^{(14)}}{q^{(14)}} = 0{,}0052260 \qquad y\,.\,0{,}40949 - 0{,}00214 = -x(14)$$

$$\frac{b^{(6)}}{q^{(6)}} = 0{,}0037136 \qquad y\,.\,0{,}12387 - 0{,}00046 = x(6)$$

The coefficients of y in these equations are the values of $h^{(1)}$, $h^{(2)}$, &c. hence $h^{(1)} = 0.04022$, $h^{(2)} = 0{,}14095$, $h^{(3)} = 0{,}13143$, &c. instead of which La Place has used the values of the coefficients $\frac{b^{(1)}}{q^{(1)}}, \frac{b^{(2)}}{q^{(2)}}$, &c. contained in the system (P′) putting $h^{(1)} = 0{,}0067131$, $h^{(2)} = 0{,}0058886$, &c. and *in this consists the greatest of his mistakes.* For by using these erroneous values of $h^{(1)}$, $h^{(2)}$, &c. their sum becomes 0,0824899; which he puts equal to F, and as the sum of the *six* first of these terms is $0{,}0358526 \lessdot \frac{1}{2}$ F, and the sum of the *seven* first of them is $0{,}0415250 \gtrdot \frac{1}{2}$ F, he puts $r = 7$, and makes the error of the *seventh* of the equations (P″) equal to nothing, that is $x^{(13)} = 0$, consequently $y = \frac{b^{(13)}}{q^{(13)}} = \frac{0{,}00178}{0{,}31380} = 0{,}0056724$, and then the equation (B″) gives $z = 0{,}99923 - y.\ 0{,}43529 = 0{,}99676$, whence the ellipticity of the earth represented in general by $0{,}00865 - y$ becomes $0{,}0029776 = \frac{1}{335.8}$. This is nearly the value given by La Place; but if we use the correct values $h^{(1)} = 0{,}04022$, $h^{(1)} = 0{,}14095$, &c. the sum of all of them will be F = 4,06894, now as the sum of the *seven* first terms is $1{,}80459 \lessdot \frac{1}{2}$ F, and the sum of the *eight* first terms is $2{,}21755 \gtrdot \frac{1}{2}$ F, we ought by

the formulas (Q) to put $r = 8$, consequently the error of the eighth of the equations (P″) ought to be put equal to nothing, that is $x^{(15)} = 0$, which gives $y = \frac{l^{(15)}}{q^{(15)}} = \frac{0,00225}{0,41300} = 0,0054479$. The equation (P″) gives $z = 0,99923 - y.\ 0,43529 = 0,99686$, and the ellipticity of the earth $0,00865 - y$ becomes $0,0032021 = \frac{1}{312}$, instead of $\frac{1}{335.78}$, found by La Place.* Thus we perceive the effect of this main error of the computation.

There is also another error existing in the tenth of the equations (A″) corresponding to the observation at Gotha, but as this did not affect the result so materially as the preceding one, I have thought proper to defer noticing it till this time in order that the regular chain of the calculation might not be interrupted. This error consists in putting the coefficient of y in that equation equal to 0,57624, whereas its true value is 0.60339. For the latitude of Gotha being 56°,63 [corresponding to 50° 58′ 1″,2 in sexagesimals] its log. sine by Callet's Tables is 9,8902999, the double of this logarithm is 9,7805998 corresponding to the natural number 0,60339, which is the correct value of the coefficient of y. If we decrease the logarithm taken from the table by 0,01, making it 9,8802999, (which is a mistake very easily made in those tables, because the numbers 9,89 are marked at the top of the column, and 9,88 at the bottom and the remaining five figures

* To prove *a posteriori* that the corrected value of y makes the sum of the errors $x^{(1)}$, $x^{(2)}$, &c. less than La Place's value of y; I computed that sum, with both values to seven places of decimals. La Place's sum was, 0,00123, the corrected sum 0,00113, whence we evidently perceive that La Place's value does not produce a *minimum* of error, as it ought to have done if his calculation had been made correctly.

02999 are found in the column itself), the double of the logarithm will become 9,7605998, corresponding to the number 0,57624 used by La Place. Whence we readily perceive the cause of this mistake. We shall now proceed to calculate the corrected values of z and y, and the ellipticity of the earth by rectifying both these mistakes. The tenth of the equations (A″) will become $1{,}00006 - z - y.\ 0{,}60339 = x^{(10)}$, the others remaining unchanged; this will increase the coefficient of y in (B″) by $\frac{1}{15}$th part of the difference between 0,60339 and 0,57624, or $\frac{0{,}02715}{15} = 0{,}00181$, so that the equation (B″) will become

$$0{,}99923 - z - y.\ 0{,}43710 \qquad \text{(B}''\text{)}$$

and when this is subtracted from each of the equations, (A″) to obtain the equations (O″), it will produce a correction of $+ y.\ 0{,}00181$, in each of those equations, besides the correction of the tenth equation $- y.\ 0{,}02715$, so that these corrected equations will be

$$
\begin{aligned}
-0{,}00254 + y\,.\,0{,}43710 &= x^{(1)}\\
-0{,}00234 + y\,.\,0{,}40958 &= x^{(2)}\\
-0{,}00213 + y\,.\,0{,}39440 &= x^{(3)}\\
-0{,}00178 + y\,.\,0{,}34161 &= x^{(4)}\\
-0{,}00195 + y\,.\,0{,}33694 &= x^{(5)}\\
-0{,}00046 + y\,.\,0{,}12568 &= x^{(6)}\\
0{,}00027 - y\,.\,0{,}03841 &= x^{(7)}\\
0{,}00064 - y\,.\,0{,}11886 &= x^{(8)}\\
0{,}00077 - y\,.\,0{,}12962 &= x^{(9)}\\
0{,}00083 - y\,.\,0{,}16629 &= x^{(10)}\\
0{,}00095 - y\,.\,0{,}17534 &= x^{(11)}\\
0{,}00151 - y\,.\,0{,}28597 &= x^{(12)}\\
0{,}00178 - y\,.\,0{,}31199 &= x^{(13)}\\
0{,}00214 - y\,.\,0{,}40768 &= x^{(14)}\\
0{,}00225 - y\,.\,0{,}41119 &= x^{(15)}
\end{aligned}
$$

From which we obtain the same values of $b^{(1)}$, $b^{(2)}$, &c. as before; but the values of q will be altered; for we shall have $q^{(1)} = -0{,}43710$, $q^{(2)} = -0{,}40958$, $q^{(3)} = -0{,}39440$, &c. whence we obtain the corrected values of the systems of equations (P′) (P″), as follows:

$$\begin{array}{llll}
\frac{b^{(7)}}{q^{(7)}} = 0{,}00703 & & y\,.\,0{,}03841 - 0{,}00027 = -x^{(7)} & \\
\frac{b^{(9)}}{q^{(9)}} = 0{,}00594 & & y\,.\,0{,}12962 - 0{,}00077 = -x^{(9)} & \\
\frac{b^{(1)}}{q^{(1)}} = 0{,}00581 & & y\,.\,0{,}43710 - 0{,}00254 = x^{(1)} & \\
\frac{b^{(5)}}{q^{(5)}} = 0{,}00579 & & y\,.\,0{,}33694 - 0{,}00195 = x^{(5)} & \\
\frac{b^{(2)}}{q^{(2)}} = 0{,}00571 & & y\,.\,0{,}40958 - 0{,}00234 = x^{(2)} & \\
\frac{b^{(13)}}{q^{(13)}} = 0{,}00570 & & y\,.\,0{,}31199 - 0{,}00178 = -x^{(13)} & \\
\frac{b^{(15)}}{q^{(15)}} = 0{,}00547 & & y\,.\,0{,}41119 - 0{,}00225 = -x^{(15)} & \\
\frac{b^{(11)}}{q^{(11)}} = 0{,}00542 & & y\,.\,0{,}17534 - 0{,}00095 = -x^{(11)} & \\
\frac{b^{(3)}}{q^{(3)}} = 0{,}00540 & (P') & y\,.\,0{,}39440 - 0{,}00213 = x^{(3)} & (P'') \\
\frac{b^{(8)}}{q^{(8)}} = 0{,}00538 & & y\,.\,0{,}11886 - 0{,}00064 = -x^{(8)} & \\
\frac{b^{(12)}}{q^{(12)}} = 0{,}00528 & & y\,.\,0{,}28597 - 0{,}00151 = -x^{(12)} & \\
\frac{b^{(14)}}{q^{(14)}} = 0{,}00525 & & y\,.\,0{,}40768 - 0{,}00214 = x^{(14)} & \\
\frac{b^{(4)}}{q^{(4)}} = 0{,}00521 & & y\,.\,0{,}34161 - 0{,}00178 = x^{(4)} & \\
\frac{b^{(10)}}{q^{(10)}} = 0{,}00499 & & y\,.\,0{,}16629 - 0{,}00083 = -x^{(10)} & \\
\frac{b^{(6)}}{q^{(6)}} = 0{,}00366 & & y\,.\,0{,}12568 - 0{,}00046 = x^{(6)} &
\end{array}$$

Hence we get $h^{(1)} = 0{,}03841$, $h^{(2)} = 0{,}12962$, $h^{(3)} = 0{,}43710$, &c. being the coefficients of y in the equations (P″); the sum of all these

values of h is $F = 4,09066$. The sum of the *six* first terms of h is equal to $1,66364 < \frac{1}{2} F$; the sum of the *seven* first terms is $2,07483 > \frac{1}{2} F$; whence we obtain from the formulas (Q), $r = 7$, therefore the error of the seventh of the equations (P″) must be put equal to nothing or $x^{(13)} = 0$, whence we get $y = \frac{0,00225}{0,41119} = 0,005472$, and $z = 0,99923 - y$, $0,43710 = 0,99684$, consequently the ellipticity $0,00865 - y = 0,003178 = \frac{1}{314.7}$: so that the ratio of the *polar* to the *equatorial* diameter of the earth is as 314 to 315 nearly, instead of 335 to 336 found by La Place. Putting now ψ for the latitude of any place we shall have $p = \sin \psi^2$, and the general expression of the length of a pendulum $z + p\,y$ will become $0,99684 + 0,005472, \sin \psi^2$. This for the latitude of Paris becomes 0,99994, and as the actual length, according to La Place, is $0^m,741887$, the general expression of the length in metres will be found by multiplying the preceding expression by $\frac{0^m,741887}{0,99994}$, by which means it becomes

$$0^m,739587 + 0^m,004060 \sin \psi^2.$$

instead of La Place's formula $0^m,739502 + 0^m,004208, \sin \psi^2$.

The writer of the same article in the Cyclopedia objects to La Place's method of finding the ellipticity from the formula $0,00865 - y$, in which y is expressed in parts of the length of the *Paris* pendulum, whereas it ought according to that writer to be expressed in parts of the pendulum at the *equator*, or in other words, that the ellipticity ought to be $0,00865 - \frac{y}{z}$, which if we use La Place's values of z, y, would make it $\frac{1}{337.93}$ instead of $\frac{1}{335.78}$. But it may be observed, that in the investigation of the formula $0,00865 - y$, terms of the order y^2 are generally neglected, and as z

differs from unity by quantities of the order y, the difference of the two expressions $0{,}00865 - y$ and $0{,}00865 - \frac{y}{2}$, is of the same order, as the neglected terms, so that it would be difficult to determine which would be the most correct, without a new investigation of the formula, and we should conform to the degree of accuracy used in the investigation by taking for unity the length of the pendulum in *any* latitude from the equator to the pole; but in such cases it is generally found to be most accurate to take a *mean* value, and the length at Paris is much nearer to the mean value than that at the equator, so that there does not appear to be any sufficient reason for altering the calculation of La Place in this part.

SECTION SECOND.

In Book III, § 21, of La Place's *Mécanique Céleste* is given the following equation to determine the quantity λ used in finding the limit of the centrifugal force with which the equilibrium is possible in a proposed hypothesis relative to the form of the earth:

$$0 = \frac{7\lambda^5 + 30\lambda^3 + 27\lambda}{(1+\lambda^2)\,(3+\lambda^2).(9+\lambda^2)} - \text{ang. tan. } \lambda.$$

The author has not however noticed that this expression may be considerably simplified. For, by rejecting the factor $3+\lambda^2$ common to the numerator and denominator of the first term, it becomes

$$\frac{7\lambda.\,(\frac{9}{7}+\lambda^2)}{(1+\lambda^2).\,(9+\lambda^2)} - \text{ang. tan. } \lambda = 0$$

or by reduction

$$\frac{1}{8}.\,\frac{2.\lambda}{1+\lambda^2} + \frac{9}{8}.\,\frac{2.\,\frac{\lambda}{3}}{1+\left.\overline{\frac{\lambda}{6}}\right\rceil^{2}} - \text{ang. tan. } \lambda = 0$$

and since $\frac{2\lambda}{1+\lambda^2} = \text{sin. } 2\,(\text{ang. tan. } \lambda)$ this expression may be put under this simple form;

$\frac{1}{8}$. sin. 2. (ang. tang. λ) $+ \frac{9}{8}$. sin. 2 (ang. tan. $\frac{\lambda}{3}$) — ang. tan. $\lambda = 0$, from which we obtain, by a few operations with Sherwin's or Hutton's logarithms, the value $\delta = 2{,}5293$.

SECTION THIRD.

In Book 3, § 38, of the *Mécanique Céleste* the form of an osculatory ellipsoid, corresponding to any part of the earth's surface, is investigated, supposing the radius r drawn from the centre of the ellipsoid to any point of its surface to be represented by

$$r = 1 - \alpha \,.\, \text{sin.}\, \psi^2 .\, \{1 + h \,.\, \text{cos.}\, 2(\varphi + \epsilon)\} \qquad (1)$$

in which ψ is the latitude of the place, φ its longitude counted from a fixed meridian, α, h, ϵ constant quantities depending on the form of the earth, α being of the same order as the ellipticity of the earth. At the equator of this ellipsoid where $\psi = 0$, r becomes equal to unity, corresponding to an ellipsoid of *revolution*, and at the pole where $\psi = 90°$, it becomes $1 - \alpha - \alpha\, h.$ cos 2 $(\varphi + \epsilon)$, which is not constant, as it ought to be; since it contains the variable quantity φ. Therefore both these extreme values of r are defective; the one because the ellipsoid is limited to the case of *revolution*, the other because the polar axis is *variable*. To correct this we must add the term $\alpha\, h.$ cos. 2 $(\varphi + \epsilon)$ to the general expression of r, as we shall now proceed to show.

The equation of the earth's surface, assumed by La Place in his *Méc. Cél.* Vol. 2. Pag. 109, is $u = 0$, which, in page 112, is reduced to the form $0 = x^2 + y^2 + z^2 - 1 - 2\alpha u'$, x, y, z, being the rectangular coordinates of that point of the earth's surface above mentioned, whose distance from the centre is r, so that $x^2 + y^2 + z^2 = r^2$. Substituting this in the preceding equation we get $r^2 = 1 + 2\alpha\, u'$, and by neglecting the second and higher powers of α,

$$r = 1 + \alpha\, u'. \qquad (2)$$

Now the general equation of an ellipsoid, whose semi-axes are k, $\frac{k}{\sqrt{m}}$, $\frac{k}{\sqrt{n}}$, is by Pag. 8 of the above mentioned volume represented by $x^2 + m\,y^2 + n\,z^2 = k^2$ or $x^2 + y^2 + z^2 = k^2 + (1 - m).\,y^2 + (1 - n).\,z^2$, and as $1 - m$, $1 - n$, are of the order α, we may in the second member of this equation put $y = k.\cos\,\psi.\sin\varphi$, $z = k.\sin.\,\psi$, as is evident from Pag. 113, of the same work, observing that k differs from r, only by terms of the order α. Substituting these values, and those of $x^2 + y^2 + z^2 = r^2$, it becomes $r^2 = k^2.\ \{1 + (1 - m).\cos.\,\psi^2.\sin\varphi^2 + (1 - n).\sin.\,\psi^2\}$, whose square root, neglecting α^2 becomes,

$$r = k + k.\frac{(1-m)}{2}.\cos\,\psi^2.\sin\varphi^2. + k.\frac{(1-n)}{2}.\sin.\,\psi^2 \qquad (3)$$

Putting $\cos.\,\psi^2 = 1 - \sin.\,\psi^2$, and $\sin.\,\varphi^2 = \frac{1}{2} - \frac{1}{2}\cos.\,2\varphi$, we shall get

$$r = k + k.\,\overline{\frac{1-m}{4}} - k.\sin.\,\psi^2.\left\{\frac{1-m}{4} - \frac{(1-n)}{2} + \frac{m-1}{4}.\cos.2\varphi\right\}$$

$+ \frac{m-1}{4}.\,k.\cos.\,2\varphi$, and if we suppose $k + k.\overline{\frac{1-m}{4}} = 1$, we may substitute $k = 1$ in the terms multiplied by $1 - m$ or $1 - n$, and then putting $\frac{m-1}{4} = \alpha h$, $\frac{1-m}{4} - \frac{(1-n)}{2} = \alpha$, the preceding expression will become

$$r = 1 - \alpha\sin.\,\psi^2.\ \{1 + h.\cos.\,2\,\varphi\} + \alpha\,h.\cos.\,2\varphi. \qquad (4)$$

If we change the origin of the angle φ, so as to write $\varphi + \epsilon$, instead of φ, it becomes

$$r = 1 - \alpha.\sin.\,\psi^2.\{1 + h.\cos.2\,(\varphi + \epsilon)\} + \alpha\,h.\cos.\,2\,(\varphi + \epsilon). \qquad (5)$$

Comparing this with the expression (1) assumed by La Place, we find that he has neglected the last term $\alpha h.\cos.\,2\,(\varphi + \epsilon)$. When $\psi = 90°$, the expression (5) becomes $1 - \alpha$ for the polar semi-axes, and when $\psi = 0$, it becomes $1 + \alpha\,h.\cos.\,2\,(\varphi + \epsilon)$, corresponding to the variable radius of the equator of an ellipsoid which

is not of revolution. The term of r thus neglected, renders the expressions of the length of an arch of the meridian, and that of the perpendicular to the meridian, also the azimuth angle ϖ given by La Place in Page 125, vol. 2, erroneous. The corrected values are found in the following manner.

Putting the expressions (2) and (5) equal to each other we get

$$u' = -\sin.\psi^2.\ \{1 + h.\cos.2\,(\varphi + \epsilon)\} + h.\cos.(2\,\varphi + \epsilon). \quad (6)$$

in which the last term was neglected by La Place, and if we put this term equal to u'' we shall have

$$u' = -\sin.\psi^2.\ \{1 + h.\cos.2\,(\varphi+\epsilon)\} + u'',\ u'' = h.\cos.2(\varphi + \epsilon). \quad (7)$$

This value of u'' gives $\left(\frac{du''}{d\psi}\right) = 0$, so that the expression of the length of an arch of the meridian s given in Vol. 2, Page 115, under the form

$$s = \epsilon + \alpha\epsilon.\ \left\{u_{\prime}' + \left(\frac{ddu_{\prime}'}{d\psi^2}\right)\right\} + \frac{\alpha\epsilon^2}{1.2}.\ \left\{\left(\frac{du_{\prime}'}{d\psi}\right) + \left(\frac{d^3u_{\prime}'}{d\psi^3}\right)\right\} + \&c. \quad (8)$$

will be increased by the term $\alpha\,\epsilon\,u''$; observing that ϵ represents the difference of the latitudes of the two extreme points of the arcs s, and $u_{\prime}'$ is the value of u' when $s = 0$. In Page 125, Vol. 2, La Place has deduced the following expression of s, namely,

$$s = \epsilon - \frac{\alpha\epsilon}{2}.\{1 + h.\cos.2(\varphi + \epsilon)\}.\ \{1 + 3.\cos.2\,\psi - 3\epsilon.\sin.2\,\psi\} \quad (9)$$

To which we must add the term $\alpha\epsilon\,u''$ or $\alpha\,\epsilon\,h.\cos.2\,(\varphi + \epsilon)$ by which means its correct value will be

$$s = \epsilon - \frac{\alpha\epsilon}{2}\,\{1+h.\cos.2(\varphi+\epsilon)\}.\{1+3\cos.2\psi - 3\epsilon.\sin.2\psi\} + \alpha\epsilon h.\cos.2(\varphi+\epsilon).$$

If the earth is supposed not to be a spheroid of revolution, and an arch be measured upon its surface so that the direction of its first part is parallel to the celestial meridian, and its last part forms the angle ϖ with the celestial meridian, corresponding to

that part, we shall have to determine ϖ the following expression given by La Place in Vol. 2, p. 117.

$$\varpi = -\frac{\alpha\epsilon.\tan.\psi}{\cos.\psi}.\left\{\left(\frac{du'}{d\phi}\right).\ \text{tang.}\ \psi + \left(\frac{ddu'}{d\phi d\psi}\right)\right\} \qquad (11)$$

From this he finds, by neglecting the term u'' (7), and putting $u' = -\sin.\ \psi^2.\left\{1 + h.\ \cos.\ 2(\varphi + \mathfrak{C}).\right\}$

$$\varpi = -2\,\alpha\,h\,\epsilon.\ \frac{\tan\ \psi^2.\ (1+\cos.\ \psi^2)}{\cos.\ \psi}.\ \sin.\ 2\,(\varphi + \mathfrak{C}) \qquad (12)$$

which is easily deduced from (11) by using his value of u'. The term u'' (7) which he has neglected would produce in (11) the term

$$-\frac{\alpha\epsilon.\ \tan.\ \psi^2}{\cos.\ \psi}.\left(\frac{du''}{d\phi}\right) = 2\,\alpha\,h\,\epsilon.\ \frac{\tan.\ \psi^2}{\cos\ \psi}.\ \sin.\ 2\,(\varphi + \mathfrak{C})$$

By adding this to the expression (12) we obtain the corrected value of ϖ, namely

$$\varpi = -2\,\alpha\,h\,\epsilon.\ \frac{\tan.\ \psi^2.\ \cos.\ \psi^2}{\cos.\ \psi}.\ \sin.\ 2\,(\varphi + \mathfrak{C}) \qquad (13)$$

which is easily reduced to the more simple form

$$\varpi = -2\,\alpha\,h\,\epsilon.\ \sin.\ \psi.\ \tan.\ \psi.\ \sin.\ 2\,(\varphi + \mathfrak{C}) \qquad (14)$$

This corrected value is less than half of that given by La Place; for the ratio of the quantities (12), (13) is expressed by $\frac{1+\cos\ \psi^2}{\cos.\ \psi^2}$ or $1 + \sec.\ \psi^2$, which always exceeds 2.

The length of an arch of one degree, measured upon the earth's surface in a direction perpendicular to the meridian, is found by multiplying the radius of curvative R given by La Place in Vol. 2, p. 123 of his "*Méc. Cél.*" by 1°; hence it becomes

$$1°.\left\{1 + \alpha\,u_{,}' - \alpha.\left(\frac{du_{,}'}{d\psi}\right).\ \tan.\ \psi_{,} + \frac{\alpha.\left(\frac{ddu_{,}'}{d\phi^2}\right)}{\cos.\psi_{,}^2}\right\} \qquad (15)$$

$u_{,}'$ $\psi_{,}$, being the values of u', ψ, at the first point of the arch. In this we must substitute the value of u' (7). La Place neglected u'', and thence he found for this expression the following value

$$1^\circ + 1^\circ . \alpha \left\{ 1 + h . \cos . 2 \, (\varphi + \epsilon) \right\} \sin . \psi^2 + 4^\circ . \alpha h . \tan . \psi^2 . \cos . 2 (\varphi + \epsilon) \quad (16)$$

If we had retained the term $u'' = h . \cos . 2 \, (\varphi + \epsilon)$, which gives $\left(\frac{du''}{d\psi}\right) = 0$; $\left(\frac{ddu''}{d\varphi^2 .}\right) = -4 \, h . \cos 2 \, (\varphi + \epsilon)$ it would produce the correction

$$1^\circ . \alpha h \left\{ 1 - \frac{4}{\cos . \psi^2} \right\} . \cos . 2 \, (\varphi + \epsilon)$$

and since $\frac{1}{\cos . \psi^2} = 1 + \tan . \psi^2$. this may be put under the form

$$1^\circ . \alpha h . \left\{ -3 - 4 \tan . \psi^2 \right\} . \cos . 2 \, (\varphi + \epsilon)$$

which being added to the expression (16) we get the corrected value of the length of this degree equal to

$$1^\circ + 1^\circ . \alpha . \left\{ 1 + h . \cos . 2 \, (\varphi + \epsilon) \right\} . \sin . \psi^2 - 3^\circ . \alpha h . \cos . 2 \, (\varphi + \epsilon).$$

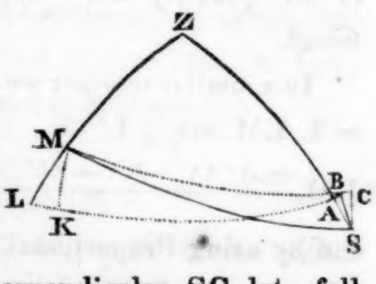
IV.

Method of correcting the apparent distance of the Moon from the Sun, or a Star for the effects of Parallax and Refraction.

BY NATHANIEL BOWDITCH, LL. D.

The method of correcting the apparent distance of the Moon from the Sun, or a Star for the effect of parallax and refraction, which was published by me in a work, entitled the "Practical Navigator," has one great advantage over other methods of approximation; namely, that *all the corrections are additive;* which renders it peculiarly well adapted for the use of mariners. It was given without demonstration, and two of the smaller corrections were neglected, as is usual in such methods. I have here drawn up a general demonstration of the formula, with tables for computing the neglected terms, from which it will appear that they are generally insensible,

Let Z be the zenith, M the true, and L the apparent place of the Moon; S the true, and A the apparent place of the Sun or Star. Upon the arch LA (continued if necessary) let fall the perpendiculars MK, SB, join MB, and continue it towards C to meet the perpendicular SC let fall thereon. Then in the case of the present figure, in which all the angles and sides of the triangle A Z L are acute, we shall have the following expression of the true distance M S.



$MS = (LA - 2^\circ) + (60' - SA) + (59' 42'' - LM) + (SA + AB)$ $+ (LM - LK) + (18'' + BM - BK) + BC + (MS - MC)$ Because the terms $-2^\circ + 60' + 59' 42'' + 18''$, $-SA + SA$, $-LM + LM$, $LA + AB - LK - BK$, $BM + BC - MC$, which occur in this expression mutually destroy each other, leaving the identical equations $MS = MS$.

Now $AB = SA . \cos A$, neglecting the third power of SA. Hence $SA + AB = SA . (1 + \cos. A) = 2 . SA . \cos. \frac{1}{2} A^2$, and if we put $ZL = 90^\circ - m$, $ZA = 90^\circ - s$, $LA = d$, $2S = d + s + m$, $S \backsim d = f$, $S - s = g$, we shall have, by the noted theorem for finding an angle of a spherical triangle when the three sides are given, namely

$$\cos. \tfrac{1}{2} A^2 = \frac{\sin \frac{1}{2}(LA + ZA + ZL) . \sin \frac{1}{2}(LA + ZA - ZL)}{\sin. ZA. \sin. LA} = \frac{\cos. f. \sin. g}{\cos. s. \sin. d},$$

hence $SA + AB = \frac{2. SA}{\cos. s} \times \frac{1}{\sin. d. \operatorname{cosec}. g. \sec. f}$ or by using proportional logarithms Prop. log. $(SA + AB) =$ Prop. log. $\frac{2. SA}{\cos. s} +$ log. sin. d + log. cosec. g + log. sec. f.

To simplify this calculation, I have computed and published in the "Practical Navigator" the tables, numbered XVII (or XVIII), in which by a single entry may be found the quantity $60' - SA$, and the Prop. log $\frac{2. SA}{\cos. s}$, and then by the preceding formula the quantity $SA + AB$, called the *first correction*, is to be found.

In a similar manner we have $LM - LK = LM - LM. \cos. L$ $= 2. LM. \sin. \frac{1}{2} L^2 =$

$$2 LM. \frac{\sin. \frac{1}{2}(ZA + LA - ZL) . \sin. \frac{1}{2}(ZA + ZL - LA)}{\sin. ZL . \sin. LA} = 2 LM. \frac{\sin. g. \cos. S}{\cos. m \sin. d},$$

and by using Proportional logarithms, we shall get

Prop. log. $(LM - LK) =$ Prop. log. $\frac{2. LM}{\cos. m}$ + log. sin. d + log. cosec. g + log. sec. S.

This is also simplified by a Table numbered XIX, containing

the value of the quantity $59', 42'' - LM$ for all altitudes, and at the same entry the Proportional Logarithm of $\frac{2. LM}{\cos. m}$ by means of which the quantity LM — LK called the *second correction* is computed. This requires only one additional logarithm; because log. sin. d and log. cosec. g were found in making the computation of the *first correction*.

The next term in the values of MS is $18'' + BM - BK$. Now it is well known that when the arch MK is very small in comparison with BK, the difference BM — BK will be very nearly equal to $\pm \frac{1}{2} MK^2. \cot. BK$, or $\pm \frac{1}{2}. MK^2. \cot. d$: so that the term now treated of is $18'' \pm \frac{1}{2} MK^2 \cot. d$. The upper sign being used if $d < 90$, the lower if $d > 90°$. This is found by means of Table XX, which contains two vertical columns corresponding to each value of d, the arguments at the side being the quantites $60' - LM$ and $60' - LK$, or in other words the correction of Tab. XIX, and corr. Tab. XIX + second correction; the tabular numbers corresponding when $d < 90°$, being respectively $18'' + \frac{1}{2} \overline{LM}^2. \cot. d$ and $\frac{1}{2} LK^2. \cot. d$, whose difference is $18'' + \frac{1}{2}. (LM^2 - LK^2). \cot. d$ or $18'' + \frac{1}{2} MK^2. \cot. d$. When $d > 90°$, the tabular numbers are $18'' + \frac{1}{2} LK^2. \cot. d$, and $\frac{1}{2} LM^2. \cot. d$, whose difference is $18'' - \frac{1}{2} \overline{MK}^2. \cot. d$, as above. This is called the *third correction*.

Therefore if we neglect the two very small terms BC + (MS — MC) in the value of MS, it will become

$$MS = (\text{app.dist.} - 2°) + \text{corr.Tab.XVII} + \text{corr.Tab.XIX} + 1^{d}\text{corr.} + 2^{d}\text{corr.} + 3^{d}\text{corr.} \quad (A)$$

and all the terms of this expression will have the affirmative sign.

As an example of this formula, let us take the following, which is the first in the Practical Navigator, Pag. 155, Edit. 4. The apparent distance being 38° 52′, Star's app. alt. 43° 14′, ☽'s app. alt. 53° 4′. ☽'s Horiz. Parallax 54′ 35″

App. Dist.	d=38° 52′	... sine.	9.7976	. . . . . .	9.7976	d—2°	=36°52′ 0″
*App. alt.	s=43 14	g cosec.	0.3848	. . . . . .	0.3848	Tab. xvii	58 59
☽ App. alt.	m=53 4	f sec.	.0570	S. sec	0.4187	Tab. xix	27 37
2S=$d+s+m$=	135 10	Tab. xvii. log.	1.8112	Tab. xix log.	2266	Cor. 1	1 36
S	67.35	1st Corr. P.L.	2.0506	2d. corr. P.L.	8277	Cor. 2	26 46
S ∾ $d=f$	28.43					Tab xx	29
S—$s=g$	24.21						
						True distance	38 47 27

Thus we see that this method is quite short, and *it has the inestimable advantage of being free from a variety of cases in the application of the corrections, since all the terms are additive.*

The two neglected terms BC + (MS — MC) may be computed in the following manner. We have BC = BS. sin. BSC = BS. sin MBK nearly; and sin. MBK $= \frac{\text{MK}}{\sin. d}$ nearly, hence BC $= \frac{\text{BS.MK}}{\sin. d}$, but $\frac{1}{\sin. d} = \frac{2.\cos. d}{2.\sin. d.\cos d} = \frac{2.\cos. d}{\sin. 2d}$ dividing by sin. d we get, $\frac{1}{\sin. d^2} = \frac{2.\cot. d}{\sin. 2d} = 2.\cot. d.\ \text{cosec.}\ 2d$, or $\frac{1}{\sin d} =$ $2.\sqrt{\tfrac{1}{2}\cot. d.\ \text{cosec}\ 2d}$, which being substituted in BC, it becomes $\text{BC} = 2.\ \text{BS}.\ \sqrt{\tfrac{1}{2}\,\overline{\text{MK}}|^2.\cot. d} \cdot \sqrt{\text{cosec.}\ 2d}$; and this may be calculated by means of the Tables E, F, G subjoined. In Table E the argument at the top is 60′ — SA, at the side, the first correction SA + AB, the corresponding number is the value of BS $= \sqrt{\text{SA}^2 - \text{AB}^2}$ in minutes = E. In Table F the argument at the top is E, and at the side the third correction 18″ ± $\tfrac{1}{2}$ MK^2. cot. d, the tabular number corresponding being

$\text{F} = \tfrac{1}{2}\sqrt{\left\{\text{BS}\sqrt{\tfrac{1}{2}.\ \overline{\text{MK}}|^2.\cot. d}\right\}} = \tfrac{1}{2}\sqrt{\text{E}}.\ \sqrt[4]{\tfrac{1}{2}\text{MK}^2.\cot d}.$ expressed in minutes. Then in Table G, the argument at the top is d, and at the side F, corresponding to which is the expression of

$BC = 8F^2 . \sqrt{\text{cosec. } 2d}$, in seconds. This is usually called the *fourth* correction, and is the same as the *fourth correction* of Witchell's method, which is generally neglected.

The last term $MS - MC$ is equal to $\frac{1}{2}. SC^2. \text{cot. } d$, or $\frac{1}{2} E^2. \text{cot. } d$, nearly. This is found in Table H, the argument at the side being E, and at the top *d*. It is called the *fifth correction*, and within the limits of the present table it is additive like the other corrections, though in fact, if it were of any sensible magnitude, it would be subtractive when the distance is above 90°, but for such distances and for altitudes exceeding 5° this correction is only a fraction of a second, and it is in all cases neglected by Witchell and Lyons.

Table E.

Find at the top the correction of Tab. XVII or Tab. XVIII, and at the side the first correction, and call the corresponding number E.

	49′	50′	51′	52′	53′	54′	55′	56′	57′	58′	59′	60′
0′	0′	0′	0′	0	0′	0′	0′	0′	0′	0′	0′	0′
1	5	4	4	4	4	3	3	3	2	2	1	0′
2	6	6	6	5	5	4	4	3	3	2	0	
3	8	7	7	6	6	5	5	4	3	2		
4	8	8	7	7	6	6	5	4	3	0		
5	9	9	8	7	7	6	5	4	2			
6	10	9	8	8	7	6	5	3				
7	10	10	9	8	7	6	5	3				
8	11	10	9	8	7	6	4	0				
9	11	10	9	8	7	5	3					
10	11	10	9	8	6	4	0					
11	11	10	9	7	6	3						
12	11	10	8	7	5	0						
13	11	10	8	6	4							
14	11	9	7	5	0							
15	10	9	7	4								
16	10	8	6	0								
17	9	7	4									
18	8	6										
19	8	4										
20	6	0										
21	5											
22	0											

Table F.

Find E at the top, and the correction Tab. XX at the side, and call the corresponding number F.

		0	½′	1′	2′	3′	4′	5′	6′	7′	8′	9′	10′	11′
18″	18″	0′	0′	0′	0′	0′	0′	0′	0′	0′	0′	0′	0′	0′
17	19	0	1	1	2	2	3	3	3	4	4	4	4	5
16	20	0	1	2	2	3	3	4	4	4	5	5	5	5
14	22	0	2	2	3	3	4	4	5	5	6	6	6	6
11	25	0	2	2	3	4	4	5	5	6	6	7	7	7
9	27	0	2	2	3	4	5	5	6	6	7	7	8	8
6	30	0	2	3	4	4	5	6	6	7	7	8	8	8
1	35	0	2	3	4	5	6	6	7	7	8	8	9	9
	40	0	2	3	4	5	6	7	7	8	8	9	9	10
	45	0	2	3	4	5	6	7	8	8	9	9	10	10
	50	0	2	3	5	6	7	7	8	9	9	10	10	11
	55	0	2	3	5	6	7	8	8	9	10	10	11	11
	60	0	2	4	5	6	7	8	9	9	10	11	11	12
	65	0	3	4	5	6	7	8	9	10	10	11	11	12
	70	0	3	4	5	6	7	8	9	10	10	11	12	12
	75	0	3	4	5	7	8	8	9	10	11	11	12	13
	80	0	3	4	5	7	8	9	9	10	11	12	12	13
	85	0	3	4	6	7	8	9	10	10	11	12	12	13
	90	0	3	4	6	7	8	9	10	11	11	12	13	13
	95	0	3	4	6	7	8	9	10	11	12	12	13	14

Table G.

Find the app. dist. at the top, and F at the side, the corresponding number is the fourth correction additive.

										20°	25°	30°	35°	40°	45°
	89°	88°	86°	84°	82°	80°	78°	75°	72°	70°	65°	60°	55°	50°	45°
	91°	92°	94°	96°	98°	100°	102°	105°	108°	110°	115°	120°			
0′	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″
1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
3	7	5	3	3	2	2	2	2	2	2	1	1	1	1	1
4	12	8	6	5	4	4	4	3	3	3	3	2	2	2	2
5		13	9	8	7	6	5	5	5	4	4	4	4	4	3
6				11	10	9	8	7	7	6	6	5	5	5	5
7						12	11	10	9	9	7	7	7	7	7
8							14	13	12	11	10	10	9	9	9
9									15	14	13	12	12	11	11
10										17	16	15	14	14	14
11										21	19	18	17	17	17
12										25	23	22	21	20	20
13										29	27	25	24	24	24

Table H.

Find the app. dist. at the top, and E at the side, the corresponding number is the fifth correction.

	10°	20°	30°	40°	50°	60°	70°
0′	0″	0″	0″	0″	0″	0″	0″
5	1	1	0	0	0	0	0
8	3	2	1	1	0	0	0
10	5	2	2	1	1	1	0
11	6	3	2	1	1	1	0

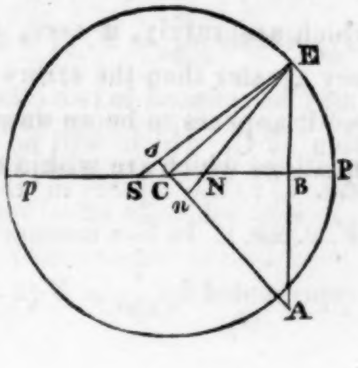
Thus in the preceding example, we have $E = 1'$, $F = 2'$, hence the fourth correction in Table G is $1''$. The fifth correction in Table H is less than a second. Both these corrections are insensible; and this is generally the case except the distance of the objects is very small, and the altitudes very low; but observations are rarely made in such circumstances, on account of the uncertainty of the refraction near the horizon, which is a much greater source of error than the corrections now under consideration. For a variation of ten degrees in Fahrenheit's thermometer would produce an alteration of $15''$ in the refraction of a body, situated $5°$ above the horizon; this might produce a correction of the same order in the true distance, which would in general be much greater than the sum of the fourth and fifth corrections. Now as Navigators do not usually notice the corrections depending upon the thermometer and barometer, it becomes necessary to avoid those observations, in which the corrections for temperature and density would be great, or in other words, the low altitudes. But if the objects are sufficiently elevated to render the corrections for the temperature and density small, the fourth and fifth corrections will be hardly sensible, so that for all practical purposes, it will be sufficient to notice the rest of the corrections in the preceding formula (A) and neglect the two last. In addition to this we may observe that the quantities thus neglected are not in general greater than those depending upon the spheroidal form of the earth, which are rarely, if ever, taken into consideration; neither are they greater than the errors to which the lunar tables are liable, and it appears to be an unnecessary degree of accuracy to notice equations which are within the limits of the errors of those tables.

V.

On the method of computing the Dip of the Magnetic Needle in different latitudes, according to the theory of Mr. Biot.

BY NATHANIEL BOWDITCH, LL. D.

An article upon the "Variations of the Terrestrial Magnetism in different latitudes," published in vol. 22 of Tilloch's Philosophical Magazine for the year 1805, contains the formulas discovered by Messrs. Biot and Humbolt, which represent with a considerable degree of accuracy all the observations of the Dip of the Magnetic Needle that have been made in various parts of the world, particularly in the northern hemisphere. The same subject is continued in another paper in the 49th volume of the same work for the year 1817, in which there is a small alteration in the formula; but the method may be yet considerably simplified, as will be shown in the present paper, in which I shall briefly mention the principles of Mr. Biot's theory, his formulas, and the improvement of which those formulas are susceptible.



According to this theory there are *two magnetic poles* P, *p*, upon the earth's surface, the northern in the latitude of 78° N, and in the longitude of 25° W. from Paris nearly; the southern in 78° S. and 155° E. nearly. The line P *p* joining these two poles is called the *magnetic axis*. The plane P E *p*

passing through this axis, and any proposed place E upon the earth's surface, is the *magnetic meridian* of that place. The plane passing through the earth's centre C, perpendicular to the magnetic axis, is the *magnetic equator*. The *magnetic latitude* is counted from this equator, and is equal to the complement of the angle P C E.

Upon the magnetic equator the dip is nothing or very small, and at the magnetic poles is nearly equal to 90°. In any other place the dip is computed upon the principle that the whole magnetic force of the earth is concentrated in two *magnetic points* S, N, situated in the magnetic axis P *p*, at infinitely small equal distances from the earth's centre C. The forces of both these magnetic points are supposed to be equal to each other; the one being *attractive*, the other *repulsive*, both of them varying inversely as the square of their distances from any attracted point E of the surface.

Suppose the earth to be of a spherical form, and let its radius $CP = CE = 1$, also $CS = CN = x$, the magnetic latitude of the point E equal to λ, and the angle $PCE = u = 90° - \lambda$. Then drawing the line $s\,C\,n$ perpendicular to EC, we shall have nearly $Ss = Nn = x.\ \sin.\ \lambda$; $Cs = Cn = x.\ \cos.\ \lambda$, and as x is supposed to be infinitely small we shall have, by neglecting x^2, x^3, &c. $EN = CE - Nn = 1 - x.\ \sin\ \lambda$; $ES = CE + Ss = 1 + x.\ \sin\ \lambda$; and if the magnetic force of either of the points S, N, upon a place at the distance 1 is F, the force of the point N upon E will be by hypothesis $\frac{F}{EN^2} = F.\ (1 + 2.\ x.\ \sin.\ \lambda)$ in the direction E N. This may be reduced to two other forces; the one in the *vertical* direction E C, which will be represented very nearly by $F\ (1 + 2x.\ \sin.\ \lambda)$; the other in the horizontal direction C n equal to $F.x.\cos.\ \lambda$. In like manner the repulsive force of the point S will be represented by $\frac{F}{ES^2} = F\ (1 - 2x\ \sin.\ \lambda)$ in the direction S E, which

may also be reduced to the vertical force in the direction C E, represented by F $(1 - 2x \sin. \lambda)$ nearly, and the horizontal force in the direction s C or C n, equal to F. x. cos. λ. The sum of these vertical forces which act in opposite directions is F. $(1 + 2x. \sin. \lambda) - F(1 - 2x. \sin. \lambda) = 4$ F. x. sin. λ; and the sum of the horizontal forces is F $(x. \cos. \lambda + x \cos. \lambda) = 2$ F. x. cos. λ. Representing the first of these forces by the line E C, and the last by the line C A, taken in the direction C n, the line E A will represent the direction of the magnetic needle, and the angle C E A will be the complement of the dip; so that if we represent the dip by i, we shall have C A E $= i$; and since tang. C A E$=\frac{\text{CE}}{\text{CA}}$, we shall have by using the preceding values, tan. $i = \frac{4 \text{F} x . \sin. \lambda}{2 \text{F} x . \cos. \lambda}$, or, by reduction, this very simple formula published by me in the year 1807, in the "Practical Navigator" without a demonstration,

$$\tan. i = 2 \tan \lambda. \qquad (1)$$

That is, *the tangent of the dip is equal to twice the tangent of the magnetic latitude.* This latitude being found by the usual rules of spherics, assuming the latitudes and longitudes of the magnetic poles before given.

Instead of this simple method, Mr. Biot (in Vol. 22. Tilloch) uses the following. He first computes the angle E B P $= \text{6}$, by this formula

$$\tan \text{6} = \frac{\sin 2u}{\frac{1}{3} + \cos. 2u} \qquad (2)$$

and then i by the following

$$i = 90^\circ - \text{6} + u. \qquad (3)$$

Substituting in this last, the value of $u = 90 - \lambda$, we get $\text{6} = 180^\circ - (i + \lambda)$, whence tan. $\text{6} = -$ tan. $(i + \lambda)$. and then by means of the equation (2) we get

$$\tan. (i + \lambda) = \frac{\sin. 2\lambda}{\cos. 2\lambda - \frac{1}{3}}. \qquad (4)$$

which is the form finally assumed by Mr. Biot, in the 49th vol. of Tilloch's Magazine; and it is evidently much more complex than the formula (1) mentioned above; but we may deduce formula (4) from formula (1), in the following manner. By a well known theorem $\tan.(i+\lambda)=\frac{\tan.i+\tan.\lambda}{1-\tan.i.\tan.\lambda}$; substituting the value of $\tan. i = 2\tan.\lambda$, it becomes $\tan.(i+\lambda)=\frac{3\tan.\lambda}{1-2\tan.\lambda^2}$. Multiplying the numerator and denominator by $\cos.\lambda^2$. we get $\tan.(i+\lambda)=\frac{3\sin.\lambda\cos.\lambda}{\cos.\lambda^2-2\sin\lambda^2}=\frac{3.\sin.\lambda.\cos.\lambda}{1-3.\sin.\lambda^2}$. Substituting in this the well known values $2.\sin\lambda \cos\lambda=\sin.2\lambda$, and $\sin.\lambda^2=\frac{1}{2}-\frac{1}{2}.\cos.2\lambda$, it becomes $\frac{\frac{3}{2}.\sin.2\lambda}{-\frac{1}{2}+\frac{3}{2}.\cos.2\lambda}$ and dividing the numerator and denominator by $\frac{3}{2}$, $\tan.(i+\lambda)=\frac{\sin.2\lambda}{\cos.2\lambda-\frac{1}{3}}$, which is the same as Mr. Biot's formula (4)

As the tangents of small angles are very nearly proportional to the angles themselves, the formula (1) will become, when the latitudes are small,

$$i=2\lambda.$$

that is, *the dip is then very nearly equal to twice the magnetic latitude.* This was observed by Mr. Biot, in his paper published in Tilloch's Magazine, vol. 49.

Notwithstanding the great elegance and originality observable in the various publications of Mr. Biot; it is not uncommon to find his expressions not reduced to their most simple form, as in the instance just noticed. For example, we may mention that which occurs in the "Memoires de la Classe des Sciences Mathematiques et Physiques de l'Institut de France," 1809, p. 89, where the value of $\frac{ddz}{dx^2}$ is computed by this complicated expression neglecting a factor $-mA$

$$\frac{(1+\cos. 6\, I) \,.\, \tan. 3\, I^3}{2.(\sin. 2\, I+\sin. 4\, I)^3}$$

which may be reduced to the form

$$\frac{1}{8. \cos. 3\, I. \cos. I^3}$$

by putting $1+\cos. 6\, I = 2. \cos. 3\, I^2$; $\sin. 2\, I+\sin. 4\, I = 2. \cos. I. \sin. 3\, I$; $\tan. 3\, I = \frac{\sin. 3\, I}{\cos. 3\, I}$, and reducing the expression which arises from this substitution. By this means the two complicated factors spoken of in Pag. 90 of the same work, namely $\frac{1+\cos. 6\, I.}{2(\sin. 2\, I+\sin. 4\, I)}$ and $\tan. 3\, I^3$, are replaced by the more simple ones $\frac{1}{\cos. I^3}$ and $\frac{1}{\cos. 3\, I}$.

9

VI.

Remarks on the methods of correcting the elements of the orbit of a comet in Newton's "Principia," and in La Place's "Mécanique Céleste."

BY NATHANIEL BOWDITCH, LL. D.

Having seen in a late edition of La Motte's translation of Newton's *Principia*, published in London in 1803, with notes, an attempt of the late Mr. Emerson to prove the accuracy of two equations, given in Book III, Prop. 42, of that work, for correcting the orbit of a comet by distant observations, I have been induced to draw up the first section of the following paper, containing the investigation of the correct values of those equations; being the substance of a communication I made several years ago to the late Reverend President Willard, in which I showed that Newton's method would always make the corrections double of what they ought to be. This subject is rendered rather more interesting, from the circumstances that several of the commentators on the *Principia*, besides Emerson, as Gregory,* Le Seur and Jacquier,† have endeavoured to prove the correctness of the equations as they now stand in that work, and in none of the editions of it that I have seen, not even in the complete edition of Newton's works, published by Bishop Horsley in 1779 with notes, is any

* Elements of Astronomy, Vol. 2, Pag. 790. London, 1715.

† Tom. 4, Pag. 658, Edit. Princip. etc. Genev. 1739—1742.

doubt of their accuracy expressed or even insinuated; for this reason I hope it will not be considered as trespassing too much on the Academy to devote a little time to the explanation of this method, though it is not now much used. I shall therefore explain briefly the principles of the computation used by Newton, the true form of the proposed equations, and the cause of the error in the commentaries; and while on the subject of the method of correcting the elements of the orbit of a comet, I have thought it would not be amiss to add, in another section, some reflections upon the method that La Place has given for that purpose in the first volume of his "Mécanique Céleste;" together with some reductions in the calculations.

SECTION FIRST.

Having three geocentric longitudes of the comet at distant intervals with the corresponding longitudes of the earth and its distances from the sun, knowing also (by some previous calculations) nearly the longitude of the ascending node of the comet's orbit K, and its inclination to the ecliptic I, we may compute the true longitude of the node $K + m P$, and the true inclination $I + n Q$, (P and Q being any assumed small quantities from 20′ to 30′) by the following process, by means of three operations similar to those used in the rule called *double position* or *rule of false*, in arithmetic.

In the *first operation* the longitude of the node is put $= K$, the inclination $= I$;
second operation - - - - - - $= K + P$ - - - - $= I$;
third operation - - - - - - - $= K$ - - - $= I + Q$.

In the first operation we have the elements K, I, which determine the *assumed plane of the comet's* orbit; and then the geocentric longitudes and latitudes of the comet being known, together with the longitudes of the earth and its distances from the sun, we

may, by the usual rules of trigonometry, compute the three points of the assumed plane corresponding to the three observations of the comet. Through these three points and about the sun as a focus describe a parabola; compute the area included by the radii vectores drawn from the sun to these points, and the curve; and let the area described between the first and second observations be D, that between the second and third E; also T the time in which the whole area D + E would be described by the comet according to the rules of the parabolic motion; lastly put $\frac{D}{E} = G$.

Proceed in the same manner with the second operation, using K + P instead of K, and let the quantities D, E, T, G, become respectively d, e, t, g; and in like manner for the third operation, let those quantities become respectively $\delta, \epsilon, \tau, \gamma$.

Now by comparing the first and second operations we find that an increase of P in the longitude of the node has changed the quantities T, G, into t, g, by which means they have been increased respectively by $t - T, g - G$; and as this increase was owing to the variation P in the longitude if the node, it is evident that if that variation had been m times as great, or equal to m P, the increments of T and G, would have been $m.(t - T), m.(g - G)$ respectively; these quantities being always supposed to be small.

In like manner by comparing the first and third operations we find that an increase of Q in the inclination of the orbit I, changes T, G, into τ, γ, by which means they increase respectively $\tau - T$, $\gamma - G$; consequently an increment of n Q in the inclination would produce increments in the values of T, G, represented by $n.(\tau - T), n.(\gamma - G)$ respectively.

Now by adding to T and G the increments corresponding to m P, n Q, we shall have their values corresponding to the longi-

tude of the node $K+mP$, and inclination $I+nQ$, which will therefore be respectively

$$\begin{aligned} &T+m.(t-T)+n.(\tau-T);\\ &G+m.(g-G)+n.(\gamma-G). \end{aligned} \qquad (1)$$

and as the true longitude of the node is by hypothesis $K+mP$, and the true inclination $I+nQ$, the preceding values must correspond to the true orbit. Therefore if we put the first of the preceding expressions equal to the time S actually elapsed between the first and third observations, as found by observation, and the second expression equal to $\frac{C}{1}$, the ratio of the observed times elapsed between the first and second, and the second and third observations, which, as is well known, expresses also the ratio of the areas described by the *radii vectores* in the same times we shall have $S=T+m.(t-T)+n.(\tau-T)$; $C=G+m.(g-G)+n.(\gamma-G)$ which by transposition become

$$\begin{aligned} T-S&=m.(T-t)+n.(T-\tau).\\ G-C&=m.(G-g)+n.(G-\gamma). \end{aligned} \qquad (2)$$

whence we may determine m, n, and thus obtain the corrected elements of the orbit.

The equations of Newton for finding m, n, are

$$\begin{aligned} 2T-2S&=m.(T-t)+n.(T-\tau);\\ 2G-2C&=m.(G-g)+n.(G-\gamma). \end{aligned} \qquad (3)$$

and as the left hand sides of these equations are double those of the corresponding equations (2), it is evident that Newton's rule will make the values of $m+n$ double what they ought to be.

The truth of the equations (2) which I have computed will also be evident from the following simple case. Suppose that the *true* orbit was obtained at the *second* operation, then the general values of the longitude of the node, $K+mP$, and the inclination $I+nQ$, will become $K+P$, and I; that is $K+mP=K+P$,

$I + n\,Q = I$, whence we get $m = 1$, $n = 0$, and as the true orbit is supposed to be obtained in this case, we must have $t = S$, $g = C$. By substituting these values of n, t, g, in the equations (2), they become $T - S = m, (T - S)$, $G - C = m\,(G - C)$, and by rejecting the common factors $T - S$, $G - C$, we get from both of them $m = 1$, as it ought to be. But if we make the same substitution in Newton's formulas (3), they become $2\,(T - S) = m\,(T - S)$, $2\,(G - C) = m\,(G - C)$, both of which give $m = 2$, which is double of its real value just found, agreeably to the remark abovementioned. Many other cases equally simple might be shown in which the mistake is very apparent.

The commentators Le Seur and Jacquier, in their edition of the Principia, Gregory in his Astronomy, and Emerson in the work abovementioned, have attempted to prove the correctness of Newton's rules, by the following method. By comparing (as we have done) the first and second operations, they find that the increment P in the longitude of the node, increases the time T by the increment $t - T$, whence they find by the rule of three, that the increment $\frac{T - S}{T - t} \cdot P$ in the longitude of the node would produce an increment $S - T$ in the time T, by which means it would become equal to the *observed* value S, they then put $\frac{T - S}{T - t} = m$, and call the increment of the longitude of the node $m\,P$. By proceeding in the same manner with the quantities G, g, C, they find that the increment P in the longitude of the node increases the quantity G by $g - G$, and then by the rule of three they find that the increment $\frac{G - C}{G - g} \cdot P$ in the longitude of the node would produce an increment of $C - G$ in the quantity G, by which means it would become equal to the value C deduced immediately from the obser-

vations, *and then without any proof, they erroneously put* $\frac{G-C}{G-g}=m$, which ought not to be done except in the *particular* case, where the *true* inclination of the orbit is *accidentally* used at the first observation. It being very evident that if by simply changing the elements K, I into $K+mP$, I, the quantities T, G, change into S, C, corresponding to the *actual* observations, the last mentioned elements $K+mP$, I, must be the true ones, consequently the *true* inclination I must have been used at the first observation. This is the main source of the error of their demonstrations. The same process is used with the first and third operations, using the quantities n, τ, γ instead of m, t, g, and by the same erroneous method they get these equations $\frac{T-S}{T-\tau}=n$, and $\frac{G-C}{G-\gamma}=m$. By multiplying these four equations by the denominators of the terms in the left hand side they get

$T-S=m(T-t)$, $T-S=n(T-\tau)$; $G-C=m(G-g)$, $G-C=n(G-\gamma)$.

The sum of the two former is

$2T-2S=m(T-t)+n(T-\tau)$; $2G-2C=m(G-g)+n(G-\gamma)$

which are the erroneous equations given in the *Principia*.

SECTION SECOND.

A method of correcting the elements of the orbit of a comet is given by La Place, in Page 225 &c. Vol. 1 of his "*Mécanique Céleste*," in which he first computes, in an approximative manner, the perihelion distance D of the comet and the time T of passing the perihelion. These elements were selected with the expectation that they would afford a more simple calculation than any other combination, by avoiding superfluous operations. This method, however, when a great number of observations are combined, leads to very laborious calculations, and the simplicity of the com-

putation is restricted to the case in which that number is small. To render this evident, we shall give briefly the principles of his calculation.

It is founded upon the supposition that the angular distance V between the heliocentric places of the comet at the times of two observations is computed by *two different methods*, the one depending chiefly upon the observations actually made upon the comet, and the other upon the mean anomalies computed by means of the approximate elements D, T, above mentioned. If the value of V resulting from both these calculations is the same, we may generally infer that the elements D, T, are correct; but if they do not agree, as will almost always be the case, their difference must be put equal to m. This operation is repeated a second time, using the elements $D + D'$, T, instead of D, T, respectively; D' being a very small quantity or part of D, as for example $\frac{D}{50}$; by this means the error m in the angle V is changed into n. In a third operation the elements are D and $T + T'$, T' being a small time, as for example, half a day, and in this operation the difference of the angle V is equal to p. Supposing then the corrected elements to be $D + u\,D'$, $T + t\,T'$, we easily deduce from these expressions the following equation

$$(m-n) \,.\, u + (m-p) \,.\, t = m \qquad (1)$$

By the combination of the second and third observations, in a similar manner we obtain another equation of the same form

$$(m'-n') \,.\, u + (m'-p') \,.\, t = m' \qquad (2)$$

m', n', p', being the values of m, n, p, corresponding to this case.

From these two equations the values of u and t may be found, and thence the corrected elements $D + u\,D'$, $T + t\,T'$. If the corrections thus obtained are very small, and the observations are accurate, the result will in general be nearly correct, otherwise the operation must be repeated.

The combination of the second and third observations would produce another equation similar to the two just mentioned, and there might be cases where it would be advantageous to use this last one rather than the others, as for example, when the first observation was not made under so favourable circumstances, or was not so accurate, as the second and third; in which case it would be better to use the first and third equations, rather than the first and second. In this way with n observations we might obtain $n.\frac{n-1}{2}$ equations, by the combination of the observations *two* by *two*: all these equations are not however equally proper for the calculation of the values of u, t. For, when the interval between the two observations is small, the errors, to which they are liable, might have a very sensible effect on the equation deduced from them. Such equations being rejected, the rest may be combined together in the manner pointed out by La Place in Pag. 230, Vol. 1, of his "*Mécanique Céleste*," so as to obtain a more accurate result than when two equations only are used.

This method is simple and elegant, with a small number of observations; but when the number is large, there is an objection to this and to other similar methods, (like that of Newton, before mentioned,) arising from the *great number* of the equations, and the difficulty of selecting the most accurate, and those best adapted to the purpose of the calculation; because the errors of the two observations are so combined with each other, that it is difficult to appreciate the degree of accuracy of the resulting equation. Thus if the first observation was suspected not to be perfectly good, but the second and third were known to be accurate, the first and second equations would partake of the error of the first observation; but to how great a degree would not be very evident. This difficulty seems to balance in some degree the simplicity produced by

the use of *only* two elements D, P, even in the case where a few observations only are used. But when a very great number of observations are combined, and much accuracy is required, (as is the case generally, when the elliptical orbit is investigated,) the comparative simplicity of the method in which each observation is separately considered, and *all* the elements are varied, is very much increased, and the labour of calculation is less than in the method of La Place. To render this evident, we shall here give a brief sketch of the method of computing each observation, as taught by Euler, in his "Theoria Motuum Planetarum," etc. and illustrated by an example in the paper on the comet of 1807, in Vol. 3, Part 1 of the Memoirs of the American Academy of Arts and Sciences; also by Mr. Burkhardt in the "*Memoires de l'Institut* &c." 1806, Pag. 12 &c. where he has applied it to the orbit of the comet of 1770. This method of calculation was selected for the comparison on account of the simplicity of its *principles,* though it might require a more laborious *numerical calculation* than some modern methods.

Suppose the approximate values of the elements of the orbit to be represented by the following symbols, namely: The perihelion distance = D. Time of passing the perihelion = T. Place of the Perihelion counted upon the orbit of the comet = P. Place of the ascending node of the comet's orbit = N. Inclination of the comet's orbit to the ecliptic = I. With these elements we must for a *first* operation compute the geocentric longitude and latitude of the comet at the time of any observation. The same thing must be done in five successive operations, varying *one* of the elements in each operation, the others remaining unaltered. Thus in the calculation of the comet of 1807, the quantity D was changed into $D + 0.004$, in the *second* operation. T into $T + 0^{d}.05$ in

the *third.* P into $P+10'$ in the *fourth.* N into $N-10'$ in the *fifth*; and I into $I+10'$ in the *sixth*. Then representing the longitude (or latitude) computed in these successive operations by L', L'', L''', L^{iv}, L^{v}, L^{vi}, respectively, and the corresponding observation by L; also the true elements of the orbit by $D+0.004.d$; $T+0.05.t$, $P+10'.p$, $N-10'.n$, $I+10',i$, each observed *longitude* and *latitude* will furnish an equation of this form,

$$0=(L-L')+(L'-L'').d+(L'-L''').t+(L'-L^{iv}).p+(L'-L^{v}).n+(L'-L\ ).i \qquad (3)$$

so that n observations would furnish $2n$ equations, each of which would be wholly independent of the others, and from this circumstance we are better able to judge of the probable degree of accuracy in each of them, and the propriety of retaining and using any one of them in the subsequent calculations, which is a very great advantage in this method. It has however the inconvenience of requiring more labour when the number of observations is small, than the method of La Place does, because it takes more time or labour to compute an equation of the form (3) than of the form (1). But as the number of observations increases, this difference decreases, and by still increasing the number the method (3) finally becomes the most simple. Suppose for example that the labour of computing *one* equation of the form (3) was greater than that of the form (1) in the ratio of l to 1; the labour of computing all the $n.\frac{n-1}{2}$ equations of the form (1) would be to that of the $2n$ equations of the form (3) as $n.\frac{n-1}{2}$ to $2nl$, or as $n-1 : 4l$. The value of l varies with the number of observations. When that number is small it does not exceed 1 or 2, and never exceeds 4, so that when $n=17$, or even much less, the labour of computing the equations (3) will not exceed that of the equations (1), and when n exceeds that quantity, it will be the least laborious to compute the equations (3); and these last mentioned equations will have

the great advantage of being wholly independent of each other. The remarks made on La Place's method may be applied to Newton's, treated of in the preceding section, and to other similar methods.

SECTION THIRD.

The heliocentric longitudes β, β', and the heliocentric latitudes ϖ, ϖ', of a comet being given, the angular distance V is computed by La Place by the following method in Pag. 227, Vol. 1, of his *Mécanique Céleste*. The auxiliary angle A is found by this formula,

$$\sin. A^2. = \cos. \tfrac{1}{2}(\beta' - \beta)^2. \cos. \varpi. \cos. \varpi'.$$

and then V by the formula

$$\sin. \tfrac{1}{2}V^2 = \cos. (\tfrac{1}{2}\varpi + \tfrac{1}{2}\varpi' + A). \cos. (\tfrac{1}{2}\varpi + \tfrac{1}{2}\varpi' - A).$$

But this computation may be made more easily in the following manner. Find the auxiliary angle B by the formula

$$\cot. B = \cot. \varpi'. \cos. (\beta' - \beta)$$

taking B *acute* in the first or last quadrant of the value of $\beta' - \beta$, otherwise *obtuse*. Then find V by the formula

$$\cos. V = \frac{\sin \varpi'. \cos. (B \mp \varpi)}{\sin. B}.$$

The sign + is used when the latitudes ϖ, ϖ' are of different names, otherwise the sign —. This method is easily deduced from the common rules of spherical triangles applied to the triangle formed by the arch V and the two arcs of latitudes $90^\circ - \varpi$, $90^\circ - \varpi'$, meeting in the pole of the ecliptic. Then a perpendicular being let fall from the extremity of the side $90^\circ - \varpi'$ upon the side $90^\circ - \varpi$ it will meet this last side in a point which is distant from the ecliptic by the arch we have called B, as is evident from the formula above given, and the expression of cos. V is easily deduced from Napier's rules.

As an example of these methods suppose $\beta = 295^\circ\ 21'\ 10''$, $\beta' = 324^\circ\ 43'\ 58''$, $\varpi = 44^\circ\ 3'\ 16''$, $\varpi' = 59\ 0'\ 46''$.

By La Place's method,

$\beta' =$	324°	43′	58″		
$\beta' =$	295	21	10		
$\beta' - \beta =$	29	22	48		
$\frac{1}{2}(\beta' - \beta) =$	14	41	24	cos.	9.985 5666
				same	9.985 5666
ϖ	44	3′	16″	cos.	9.856 5352
ϖ'	59	0	46	cos.	9.711 6781
sin. A^2					2)19.539 3465
A	36	2	37	sin.	9.769 6732
$\varpi + \varpi'$	103	4	2		
$\frac{1}{2}(\varpi + \varpi')$	51	32	1		
$\frac{1}{2}\varpi + \frac{1}{2}\varpi' + A$	87	34	38	cos.	8.6260615
$\frac{1}{2}\varpi + \frac{1}{2}\varpi' - A$	15	29	24	cos.	9.9839315
					2)8.6099930
$\frac{1}{2}$ V	11	38	39	sin.	9.3049965
V =	23	17	18		

By the last method.

$\beta' =$ 324.43.58			
$\beta =$ 295.21.10			
$\beta' - \beta$	29.22.48	cos.	9.940 2101
ϖ'	59. 0.46	cot.	9.778 5543
B	62.22.34	cot.	9.718 7644
ϖ	44. 3.16		
B $- \varpi$	18.19.18	cos.	9.977 4065
ϖ'		sin.	9.933 1238
B		sin. ar. co.	0.052 5612
V	23.17.18	cos.	9.963 0915

VII.

Remarks on the usual Demonstration of the permanency of the solar system, with respect to the Eccentricities and Inclinations of the orbits of the Planets.

BY NATHANIEL BOWDITCH, LL. D.

The object of this paper is to show that the noted equation of condition between the eccentricities of the orbits of the planets, and from which it is generally inferred that those orbits will forever remain nearly circular, is not sufficient for a complete demonstration of this permanency, though it may render it highly probable by considerations of analogy.

The equation referred to is contained in Book I, § 57 of the "*Mécanique Céleste*," where it is shewn that if m, m', m'', &c. represent the masses of the planets; a, a', a'', &c. their mean distances from the sun; e, e', e'', &c. the eccentricities of their orbits expressed in parts of a, a', a'', &c. respectively; we shall have by neglecting quantities of the order of the fourth power of the eccentricities

$$m e^2 . \sqrt{a} + m' e'^2 . \sqrt{a'} + m'' e''^2 . \sqrt{a''} + \&c. = \text{constant}.$$

The signs of the radicals being all positive; and we may neglect the terms depending on the newly discovered planets, the satellites and the comets, on account of their smallness. This equation must be satisfied, whatever changes may be made in the values of e, e', e'', &c. by the secular variations of those quantities. Now in the present state of the solar system, every term of the

left hand side of this equation is small, therefore the sum, or the constant quantity on the right hand side must also be small, consequently *each term* of the equation must *always* be small; whence it has been inferred, that the eccentricities of *all* the planets must *always be small*, or in other words, that the orbits will never vary much from a circular form, so that these orbits may be considered as perfectly stable, in respect to the eccentricities, which will oscillate about the mean values, from which they will vary but very little.

But the deduction thus made from the preceding equation does not appear to be warranted to the extent usually given to it. If it had been confined to the three largest planets, Jupiter, Saturn, and Uranus, it would have been correct; but that equation may be satisfied supposing the orbits of the planets Mercury, Venus, the Earth and Mars to be extremely elliptical, parabolic, or even hyperpolic. To prove this, the values of the terms $m\,e^2\sqrt{a}$, $m'\,e'^2\sqrt{a'}$, &c. corresponding to the planets were computed roughly, as in the following table, column 5, using the values ot m, m', m'', &c. a, a', &c. e, e', &c. given in the second edition of La Place's Exposition of the system of the world. In col. 6, the values of the same terms are computed, supposing the orbits of Mercury, Venus, the Earth and Mars to be parabolic, or that $e = e' = e'' = e''' = 1$, and then by reducing the eccentricity of Jupiter less than one sixth part, the sum of the terms of the equation becomes the same as in col. 5.

Planets	$\frac{1}{m}$, $\frac{1}{m'}$, &c. The sun's mass being 1.	Mean. Dist. a, a', &c.	Eccentricities e, e', &c.	Terms of the Equation $m e^2 . \sqrt{a}$, &c.	Terms of the equation altered.
☿	2025810	0.387100	0.205513	0.00000 00050	0.00000 01190
♀	383137	0.723332	0.006885	1	16000
⊕	329630	1.	0.016814	9	30340
♂	1846082	1.523693	0.093088	88	10190
♃	1067,09	5.202778	0.048077	2 58000	2 00428
♄	3359,40	9.538785	0.056223	2 76000	2 76000
♅	19504	19.183475	0.046[illegible]83	95000	95000
			Constant quantity =	0.00006 29148	0.00006 29148

We cannot therefore conclude from the preceding equation, *independent of other considerations of analogy*, that the orbits of *all* the planets will never vary from a circular form.

A similar defect exists in the demonstration of the smallness of the inclinations of the orbits of the planets, which has been inferred from the equation

$$\text{constant} = m . \sqrt{a} . \tan. \phi^2 + m' . \sqrt{a'} . \tan. \phi'^2 + m'' . \sqrt{a''} \tan. \phi''^2 + \&c.$$

given in § 61, Book I of the "*Mécanique Céleste*," in which φ, φ', &c. represent the inclinations of the orbits to a fixed plane. For we may prove that some of the values of φ, φ', &c. may become very great without affecting that equation sensibly, as was the case with the values of e, e', &c. in the preceding equation relative to the eccentricities. It may be observed that some of the terms of the fourth power of the eccentricities and inclinations, neglected in the two equations abovementioned, *exceed* some of the terms of the second power which are retained, as is evident from the inspection of the table; which is an additional reason why those equations should be restricted to the three greater planets in the manner mentioned in this paper.

VIII.

Facts serving to show the comparative forwardness of the spring season in different parts of the United States.

BY JACOB BIGELOW, M. D.

RUMFORD PROFESSOR AND LECTURER ON MATERIA MEDICA AND BOTANY IN HARVARD UNIVERSITY.

It was suggested to me some years since by the late venerable Dr. Muhlenberg of Pennsylvania, that if a series of Calendars of vegetation should be kept for the same year in different parts of the United States, and the whole published collectively; the result would be valuable, by affording an actual view of the comparative forwardness of the season in the various latitudes and situations of the country. This suggestion was interesting to me, because it was evident that a course of observations taken on the same year would afford more accurate grounds for comparison, than any which might casually be made in different years, and subject to the variation of different seasons. As the plan was never executed by Dr. Muhlenberg, I determined to attempt carrying it into effect after his death. With this view, in the autumn and winter of 1816, I wrote to correspondents in various sections of the country, requesting them to observe and note down the time of flowering in 1817 of the common fruit trees, and a few other plants which were suggested, as being probably found in most parts of the United States. In reply to these applications I received very

seasonable and friendly communications from Stephen Elliott, Esq. at *Charleston*, S. C.—Dr. Trent at *Richmond*, Va.—Dr. Croghan at *Louisville*, and Drs. Overton and Short at *Lexington*, Ky.—Dr. Revere at *Baltimore*,—Zaccheus Collins, Esq. at *Philadelphia*,—Professor Mitchill at *New York*,—Dr. Beck at *Albany*,—Professor Cleaveland at *Brunswick*, Me. and Mr. W. Cleghorn at *Montreal*. The returns were even more numerous than I had solicited, some of the gentlemen having obligingly interested themselves to procure for me notices respecting other places than those of their own residence. I have also preserved one or two dates relating to the same subject, taken from the newspapers. The notices taken at the above mentioned places are published in order beneath.

CHARLESTON, *S. C.*

Amygdalus Persica	Peach tree	from Mar. 6 to 12
Prunus Cerasus	Cherry tree	March 24
Pyrus Cydonia	Quince tree	March 31
Pyrus Malus	Apple tree	April 4
Pyrus communis	Pear tree	April 4
Sanguinaria Canadensis	Blood root	March 20

RICHMOND, *Va.*

Amygdalus Persica		from Mar. 23 to Ap. 6
Amygdalus communis	Almond	March 10
Ulmus Americana	American elm	Mar. 3 to 15
Acer rubrum	Red maple	March 12
Pyrus malus		Ap. 10—18
Pyrus communis		Ap. 6—10
Prunus Cerasus		April 4
Syringa vulgaris	Lilac	April 13
Fraxinus Americana?	Ash	May 20

LEXINGTON, *Ky.*

Stellaria alsine	Chickweed	March 1
Ulmus Americana		March 10
Acer rubrum		March 10
Sison bulbosum, *Mx.*		March 15
Anemone hepatica var. acuta	Liverwort	March 20
Sanguinaria Canadensis		March 27
Corydalis cucullaria		April 1
Leontodon taraxacum	Dandelion	April 3
Prunus avium	May cherry	April 5
Erythronium Americanum		April 5
Amygdalus Persica		April 6--15
Corydalis aurea ?		April 7
Æsculus echinata, *Muhl.*	Buck eye	April 10
Pyrus Malus		April 10
Podophyllum peltatum	May apple	Ap. 27—Ma. 1
Geranium maculatum		April 30
Erigeron bellidifolium		April 30
Delphinium azureum		April 30
Cerastium longe pedunculatum et villosum		April 30
Syringa vulgaris		April 15
Pyrus botryapium (50 miles north)		April 15

Note. The observations at Louisville, by my friend Dr. Croghan, agreed very nearly with the above.

BALTIMORE.

Amygdalus Persica	April 9
Prunns cerasus	April 8
Pyrus Malus	April 14
Pyrus communis	April 17
Acer rubrum	April 7
Ulmus Americana	April 11
Sanguinaria Canadensis	April 4

Sorbus ancuparia	Mountain ash	May	13
Anemone nemorosa	Wood anemone	May	6
Syringa vulgaris		May	5

PHILADELPHIA.

Pothos fœtida		March	13
Alnus serrulata, *Ait.*		March	24
Anemone hepatica		April	6
Anemone thalictroides		April	8
Acer rubrum		April	10
Claytonia Virginica		April	10
Erythronium Americanum		April	14
Amygdalus Persica		April	15
Laurus Benzoin	Spice wood	April	15
Sanguinaria Canadensis		April	15
Anemone nemorosa		April	15
Saxifraga vernalis		April	15
Epigæa repens		April	15
Arabis lyrata		April	20
Prunus cerasus		April	20
Pyrus communis, malusque		April	20
Caltha palustris		April	22
Houstonia cœrulea		April	22
Leontodon taraxacum		April	22
Corydalis cucullaria		April	22
Salix longirostris		April	22

NEW YORK.

Acer rubrum		April	11
Ulmus Americana		April	11
Erythronium Americanum		April	15
Ribes rubrum et grossularia	Currant and Gooseberry	April	15
Caltha palustris		April	16

Anemone nemorosa		April	19
Claytonia Virginica		April	20
Amygdalus Persica		Ap. 21—26	
Prunus Cerasus		Ap. 25—30	
Sanguinaria Canadensis		April	26
Pyrus botryapium		April	26
Prunus domestica	Plum tree	May	1
Pyrus communis		May	2
Pyrus malus		May	4
Syringa vulgaris		May	5

ALBANY.

Anemone hepatica		April	17
Anemone thalictroides		April	26
Aquilegia Canadensis		May	1
Fragaria Virginica	Strawberry	May	8
Polygala paucifolia		May	11
Geranium maculatum		May	13
Amygdalus Persica		May	12
Pyrus communis malusque		May	15
Uvularia sessilifolia		May	13
Uvularia perfoliata		May	15

BOSTON.

Anemone hepatica	April	20
Ulmus Americana	April	20
Acer rubrum	April	22
Sanguinaria Canadensis	April	29
Saxifraga vernalis	April	29
Andromeda calyculata	May	1
Viola blanda et primulifolia	May	1
Caltha palustris	May	2
Ranunculus fascicularis	May	2

Potentilla sarmentosa, *Muhl.*	May	2
Anemone nemorosa et thalictroides	May	2
Aquilegia Canadensis	May	4
Leontodon taraxacum	May	4
Coptis trifolia, *Salisb.*	May	6
Thalictrum dioicum	May	8
Pyrus botryapium	May	8
Erythronium Americanum	May	9
Amygdalus Persica	May	9
Prunus Cerasus	May	9
Pyrus communis, malusque	May	18
Syringa vulgaris	May	22
Geranium maculatum	May	22

BRUNSWICK, *Me.*

Acer rubrum	April	28
Populus tremuloides, *Mx.*	April	28
Ulmus Americana	May	2
Alnus serrulata	May	3
Anemone nemorosa	May	5
Leontodon taraxacum	May	12
Prunus Cerasus	May	16
Pyrus communis	May	26
Pyrus Malus	May	29
Syringa vulgaris	June	8
Sorbus aucuparia	June	11

MONTREAL, *(Canada.)*

Sanguinaria Canadensis	May	1
Claytonia Virginica	May	1
Crocus vernus	May	1
Acer rubrum	May	5
Aquilegia Canadensis	May	5

Ribes grossularia	May	5
Ulmus Americana	May	10
Trillium cernuum	May	10
Amygdalus Persica	May	12
Erythronium Americanum	May	14
Caltha palustris	May	15
Leontodon taraxacum	May	15
Uvularia perfoliata	May	15
Fragaria Virginica	May	15
Tiarella cordifolia	May	24
Prunus cerasus	May	24
Pyrus communis, malusque	May	25

A letter from a gentleman at Fort Claiborne in the Alabama territory, cited in the Boston Daily Advertiser Sept. 25, states, that the Peach trees were in blossom at that place on the 4 of March.

It will be observed, that some latitude must be allowed in the exactness of the time at which the foregoing observations were made, since most of the trees and shrubs would continue in flower for one or more weeks, at any part of which time the observations might be made. It is most probable however that notice would be taken of the earliest period at which they were generally in flower. At any rate it is not likely that the statements generally would vary more than a week from this time.

The letters from Charleston, Richmond and Lexington state the spring to have been less forward than usual, and the preceding winter unusually severe. At Boston the season was not more backward than common. I am in possession of memoranda, containing the blossoming time of the fruit trees here for the last twenty years, of which that in 1817 presents nearly a fair aver-

age. The season of 1816 was cold and unfavourable to vegetation almost beyond a precedent, while that of 1817 has been marked by fine weather and unusual plenty.

In comparing the results of the different Calendars which have been presented above, it will be seen, that the Peach tree is the one which has been most uniformly returned, and it may therefore serve as a specimen for bringing into immediate comparison the advances of spring in the different parts of our country.

Places.		Lat.	Long.	Peach tree in blossom.	
Fort Claiborne	Alab. ter.	31°50′	87°50′	March	4
Charleston	S. C.	32 44	80 39	——	6 — 12
Richmond	Va.	37 40	77 50	——	23–Ap.6
Lexington	Ky.	38 6	85 8	April	6 — 15
Baltimore	Md.	39 21	77 48	——	9
Philadelphia	P.	39 56	75 8	——	15
New York	N.Y.	40 42	74 9	——	21 — 26
Boston	Ms.	42 23	70 52	May	9
Albany	N. Y.	43 39	73 30	——	12
Brunswick	Me.	43 53	69 55	——	16*
Montreal	Can.	45 35	73 11	——	12

Mr. Rich, American Consul at Valencia in Spain, informs me, that the Peach trees were in blossom there about the 19th of March. I observe from the record of Mr. Salisbury's botanical excursions this year near London, that the Apple tree flowered there May 8th.

My attempts to obtain information from some other places near the extreme boundaries of the United States were unsuc-

* No return of this tree was made from Brunswick. The date of the Cherry tree is therefore substituted, which is usually in blossom at the same time.

cessful. From the statements already given it may be inferred that the difference of season between the northern and southern extremities of the country is not less than two months and a half.

Difference of longitude does not seem very materially to affect the Floral calendar within the United States.

My best thanks are due to the gentlemen who have contributed the materials for this compilation.

Boston, Dec. 1817.

P. S. A letter received while this article was in the press, from Professor DECANDOLLE of Geneva in Switzerland, contains the following memoranda for that place in 1817.

Anemone nemorosa	March	15
Leontodon taraxacum	April	1
Amygdalus Persica	April	1
Prunus Cerasus	April	3
Pyrus communis	April	3
Caltha palustris	April	8
Pyrus Malus	April	15

IX.

SOME OBSERVATIONS ON THE SEA SERPENT.

BY W. D. PECK, A. M. F. A. A.

PROFESSOR OF NATURAL HISTORY IN HARVARD COLLEGE.

THE appearance in this vicinity the last summer of an enormous animal of the serpentine order, is a fact so remarkable here, and so interesting to naturalists every where, that the Academy at their last meeting were of opinion that some notice of it should appear in their next publication, and appointed me to consider the evidence of the fact. I beg leave to offer the following as the result of my enquiries.

The writers on Natural History for more than 2000 years have mentioned Sea-Serpents. It may not be entirely foreign to the purpose to notice what they have left us on this obscure subject. Aristotle, the father of Zoölogy, observes in Lib. II. Chap. XIV, "that there are Serpents in the sea as well as on the land, and in fresh waters. That some of those in the sea, in form resemble those of the land, except that the head has a greater resemblance to the Conger."

His ὄφις θαλαττιος, Lib. IX, Chap. 17, was probably the Conger or some other species of Muræna. The Muræna colubrina found in Amboina, M. Ophis, Serpens and Myrus, in Europe; and Mur. Echidna in the Pacific Ocean resemble serpents in their form, but are furnished with fins.

The ὕδρος and χέρσυδρος of Ælian, the Hydrus and Chersydrus of Pliny, may both be referred to Coluber Natrix of Linnæus, which frequents fresh waters, and very much resembles our own water adder, which is found in similar situations. The notion of the enormous serpents brought by Virgil from Tenedos, was probably suggested to the Greek poets from whom he took the hint, by the appearance and habits of the same Coluber Natrix, enlarged and made more terrible by poetic fancy.

The story mentioned by Pliny Lib. VIII, Chap. 14, of an enormous river serpent in Africa, was probably a fiction or great exaggeration, and was more than two centuries old when he copied it from Livy or Valerius Maximus.

It does not appear from any thing in the writings of the ancient Naturalists, that what is now called Sea-Serpent, was known in their times. It is of modern discovery and was, I believe, first mentioned by Olaus Magnus in his Historia de Gentibus Septentrionalibus. He seems to have been as credulous as Pliny, and the figure which he gives of this Serpent, as well as of other marine animals, was probably sketched from the extravagant relations of sea-faring people.

He represents the serpent he speaks of, as several hundred feet in length and in the act of taking sailors from the deck of a ship. The work of Magnus was published at Rome in 1555. In 1558 Gesner published the IVth book of his History of Animals. In this he copies the figure of Magnus with a short description as he found it, without comment. Ruysh in his Theatrum animalium, published in 1718, copies the figure of Magnus omitting the ship.

Finally the Rt. Rev. Eric Pontoppidan, Bishop of Bergen, in his Natural History of Norway, published in 1752 and 1753,

gives, on the authority of a naval officer in the Danish service, a more rational and credible account of it. The figure which he gives seems to have been made from the description of Capt. De Ferry, the officer above alluded to. In this figure, the head and jugular region are raised out of the water; a little below the head is a mane which seems to be inserted all round the back part of the neck. The appearance of this mane was most probably an optical deception, and was nothing more than the water displaced by the neck in the progress of the animal through it, returning to its level. It had probably no mane. But of the existence of the animal, the testimony* presented by the Rev. Bishop is sufficiently conclusive.

The testimony is ample of the existence of such a serpent, in the portion of the Atlantic which washes our shores.

It appears by papers sent to the Academy in the year 1810, that this Serpent was first seen in Penobscot Bay about the year 1779, by Mr. Stephen Tuckey: he compared it to an unwrought spar (meaning probably one of Spruce) which the scaly surface and dark colour of the animal would very much resemble; he thought it fifty or sixty feet in length.

The next notice is from Capt. Eleazar Crabtree, who saw it in the same Bay about the year 1785; he estimated its length at sixty feet, and its diameter he thought equal to that of a barrel, which is about twenty two inches.

In the publication of the Linnæan Society, to whose committee we are indebted for collecting the most recent testimonies on this subject, is a letter from the Rev. Mr. Jenks of Bath, who

* A letter of Capt. De Ferry, and the declaration on oath of two of his crew who were with him when he saw and shot at it.

states that in conversation with the Rev. Mr. Cummings,* the latter gentleman observed that "this animal had been seen occasionally in Penobscot Bay within thirty years; supposed to be "above sixty feet in length, and of the size of a Sloop's mast. "That it had been seen by the inhabitants of Fox and Long "Islands, and one of them a Mr. Crocket, had seen two of them "together about the year 1787.

These are the earliest notices I can find of this animal on our shores, and their truth is rendered indubitable by the evidence lately brought together by the committee of the Linnæan Society, of men of fair and unblemished character in Gloucester; of Capt. Toppan and two of his people, of the Schooner Laura of Portsmouth, and Capt. Elkanah Finney of Plymouth.

The account of it by Lonson Nash Esq. Justice of the Peace in Gloucester, from his own observation, is perfectly free from prejudice and as clear and satisfactory as can be expected of an object at the distance of two hundred and fifty yards.

Mr. Nash saw it with a perspective glass whose field of view, at that distance he found about forty five feet in diameter, and the length of the visible part of the animal, was greater than could be included in that field of view.

I do not perceive by the accounts, that any person has seen its whole length. Mr. Nash estimates it at seventy feet at least, and thinks it may be even an hundred, and its diameter equal to that of a half-barrel, about 16 or 17 inches. Its colour appeared to

* A letter from this gentleman was forwarded to the Academy about the year 1806, giving a particular account of the animal, as he saw it, at a small distance; but this letter is lost or mislaid, as are the testimony, on oath, of Capt. Crabtree and a letter from the late Capt. George Little.

him very dark, almost black. It moved by vertical undulations of the body and with great velocity, i. e. at the rate of a mile in four minutes.

In addition to Mr. Nash's account, eight persons, citizens of Gloucester,* Capt. Toppan and two of his people, on their voyage to Boston, have furnished their testimony on oath, of the presence of this animal in the harbour of Gloucester and its vicinity from the 10th to the 28th inclusive, of August last and it appears by the affidavit of Capt. Finney, that it was seen by him in June 1815, in a cove on the Plymouth shore.

The accounts of all these persons are very consistent; to the greater part it appeared to be straight, or without gibbosities or protuberances on the back; one person thought it had protuberances, but it seems probable that the upper flexures of its undulations, occasioned this opinion.

Its velocity is variously estimated; by some it was thought to move a mile in one minute, by others in three, four, or five minutes. It has great lateral flexibility, as is shewn by its turning short and moving in an exactly contrary direction, advancing the head in a line parallel with the body; hence its undulations when under water and equally surrounded by the medium, may be either vertical or horizontal at the will of the animal. The judgment of its velocity, however, without knowing its precise distance and without instruments to observe it, is extremely liable to err.

In the testimonies above referred to, the imagination seems to have had no influence, and we certainly know from them, that the existence of the animal to which they relate is indisputable; we

* Messrs. Story, Allen, Ellery, Foster, Gaffney, Mansfield, Johnson and Pearson.

know that it moves by vertical undulations, at least while near the surface of the sea; that it is laterally as flexible as other serpents; and that its motion, at times, is very swift; but our knowledge is circumscribed by these limits. It is to be hoped, that if it again visits our shores, some successful means may be devised of taking it and presenting an opportunity of completing our knowledge of so interesting a link in the chain of animated beings.

It has been seen in Long Island sound, progressing southward; it seems from this circumstance to be migratory, like the Coluber Natrix in Hungary, and may pass the winter season in Mexico or South America.

X.

An account of the violent and destructive storm of the 23d of September 1815.

BY JOHN FARRAR,

PROFESSOR OF MATH. AND NAT. PHIL. IN THE UNIVERSITY AT CAMBRIDGE.

This storm was very severely felt throughout a greater part of New England. It was most violent on and near the coast, but does not appear to have extended far out at sea. It was preceded by rain, which continued to fall for about twenty four hours with a moderate wind from the N. E. Early in the morning of the 23d the wind shifted to the east, and began to blow in gusts accompanied with showers. It continued to change toward the south and to increase in violence while the rain abated. Between 9 and 10 o'clock A. M. it began to excite alarm. Chimneys and trees were blown over both to the west and north, but shingles and slates, that were torn from the roofs of buildings, were carried to the greatest distance in the direction of about three points west of north. The greatest destruction took place between half past 10 and half past 11. The rain ceased about the time the wind shifted from southeast to south; a clear sky was visible in many places during the utmost violence of the tempest, and clouds were seen flying with great rapidity in the direction of the wind. The air had an unusual appearance. It was considerably darkened by the excessive agitation and filled with the leaves of trees and

other light substances, which were raised to a great height and whirled about in eddies, instead of being driven directly forward as in a common storm. Charles river raged and foamed like the sea in a storm, and the spray was raised to the heighth of 60 or 100 feet in the form of thin white clouds, which were drifted along in a kind of waves like snow in a violent snow storm. I attempted with several others to reach the river, but we were frequently driven back by the force of the wind, and were obliged to screen ourselves behind fences and trees or to advance obliquely. It was impossible to stand firm in a place exposed to the full force of the wind. While abroad, we found it necessary to keep moving about, and in passing from one place to another, we inclined our bodies toward the wind, as if we were ascending a steep hill. It was with great difficulty that we could hear each other speak at the distance of two or three yards. The pressure of the wind was like that of a rapid current of water, and we moved about almost as awkwardly as those do who attempt to wade in a strong tide.

The effects of this storm in many places were very terrible; much damage was done to the shipping in most of the harbours from New York to Eastport. Many vessels went ashore and bilged, many were stoved to pieces against the wharves and against each other. But the shifting of the wind prevented an excessive tide in most places. The sea had risen unusually high in Boston harbour two hours before the calendar time of high water. But the direction of the wind at this time tended to counteract the tide, and thus secured our principal seaports from that awful calamity which threatened them.* Considerable losses

* The town of Providence in Rhode Island was particularly exposed to the effects of this storm. The wind blew directly up the river on which it is built.

however were sustained by the wind alone; many old buildings and such as were slightly built or particularly exposed, were blown down; great numbers were unroofed or otherwise injured; few entirely escaped. The greatest destruction took place among trees. Our orchards and forests exhibited a scence of desolation, which has never been witnessed before to such an extent in this country. The roads in many places were rendered impassable, not only through woods, but in the more cultivated towns, where they happened to be lined with trees. Many of the streets in Boston and the neighbouring towns were strewed with the ornaments of our finest gardens and fruityards. A considerable proportion of the large and beautiful trees in Boston mall,* and in the public walk near the grainery burying ground, several of which measured from 8 to 12 feet in circumference, were torn up by the roots and prostrated. Apple trees, being separated at a considerable distance from each other, were overturned in great numbers. It was computed at the time, that no less than 5000 were blown down in the town of Dorchester alone.

unbroken by the the cape or Long Island, and in sweeping over such an extent of water it accumulated a dreadful and most destructive tide upon this flourishing place. Vessels were actually driven over the wharves and through the streets. A great number of stores and dwelling houses were destroyed with their contents, and several lives were lost. The loss of property was estimated at several millions of dollars. The great calamity which befel this town was rather owing to the extraordinary tide which rose 12 ar 14 feet above the usual mark of high water, than to the greater violence of the tempest in this place.

* It is worthy of remark, that in the several rows of trees constituting the mall, the leeward range suffered the most.

I have not been able to find the centre or the limits of this tempest. It was very violent at places separated by a considerable interval from each other, while the intermediate region suffered much less. Its course through forests in some instances was marked almost as definitely, as where the trees have been cut down for a road. In these cases, it appears to have been a moveing vortex, and not the rushing forward of the great body of the atmosphere. Yet there seems to be no part of the coast of New England which escaped its fury. Toward the interior it raged with less violence, and in Vermont and the western parts of New Hampshire, I am told that it was not noticed as particularly remarkable. Yet still further west on the St. Lawrence, the wind was so high as to render it extremely dangerous to be out in boats on the river. And what is still more remarkable, the storm began to grow violent at this place about the same time that it commenced near the Atlantic, and subsided about the same time.

There is something worthy of particular attention in the direction of the wind, at the several places where the storm prevailed. On the 22d, the wind appears to have been pretty generally from the N. E. The storm commenced, as is usual, to the leeward. But when the wind shifted from N. E. to E. and S. along the coast of New England, it veered round in the opposite direction at New York, and at an earlier period. It reached its greatest height at this latter place about 9 o'clock on the morning of the 23d, when it was from the N. W. Whereas, at Boston, it became most violent about two hours later, and blew from the opposite quarter of the heavens. At Montreal the direction of the wind was the same as at New York, but did not attain its greatest height so soon by several hours.

The wind gradually subsided in the afternoon of the 23d, and before night the sky bore its usual appearance. It was observed soon after, that a singular effect had been produced upon the leaves of vegetables near the seacoast; their vitality was destroyed, and they exhibited an appearance similar to that, which is produced by a frost, except that they retained more of their original colour, and in some instances they assumed a darker hue. This was ascribed to the spray from the salt water, which was known to have extended many miles into the country from the circumstance of window glass being covered with a thin coat of salt. The barometer descended very fast during the morning of the 23d, and when the wind was highest had fallen about half an inch. It began to rise as the wind abated, and recovered its former elevation, about 29.90, by the time the air was restored to its usual tranquillity.

It is thought that there is no account of such a storm as this to be found in the history of this part of the country. We have had hurricanes that have laid waste whatever came in their way, but they have been very limited. There was a remarkable storm of wind aud rain on the 9th of October 1804, which in some respects resembled that above described. It destroyed a number of houses, overthrew trees, chimneys and fences, but it was much less violent and less destructive.

A very remarkable gale occurred in some parts of North Carolina on the 3d of September 1815, twenty days before the one which is so often referred to amongst us. It was preceded by a storm of several days with the wind from the N. E. The wind shifted on the 3d to the N. and W. increasing in violence. It began to subside as it approached the S. W. The tide rose in

some places from 10 to 14 feet above high water mark. The loss sustained at Wilmington and other places was similar to that which was experienced here on the 23d. The roads were impassable for several days on account of the fall of trees, and much damage was done to the crops of corn and tobacco.

XI.

An account of a singular electrical phenomenon, observed during a snow storm accompanied with thunder.

BY JOHN FARRAR,

PROFESSOR OF MATH. AND NAT. PHIL. IN THE UNIVERSITY AT CAMBRIDGE.

On the evening of the 17th of January 1817, there was a remarkable thunder-shower, which extended through a great part of the United States. It took place about the same time at Brunswick, in the District of Maine, at Boston and Williamstown, at Andover, Vermont, at Philadelphia, and at Savannah, Georgia. At Boston and several places in the interior, there was rain and snow; at other places only snow, and this in great quantity and accompanied with almost incessant thunder and lightning. There were other electrical appearances also, that were particularly remarkable.

The following is taken from the meteorological register of Professor Cleaveland.

"In the earlier part of the evening, the wind was blowing from the N. E. and the thermometer descended to 17°.5. But after a short calm, the wind suddenly changed to S. E. attended at first by snow and rain and flashes of lightning. The thermometer rose rapidly, while the barometer fell to 28.89. At this time three persons crossing the bridge over the Androscoggin, observed the borders of their hats to be luminous, and when they held up their hands covered with woollen gloves, the ends of their fingers were also luminous. These appearances were observed on the bridge only."

I am informed also by another observing and intelligent gentleman,* who had collected a number of facts relating to this extraordinary phenomenon, from persons in whom he placed the highest confidence, that at Williamstown, it was seen by a physician on the ears and hair of his horse's head, on the whip of a young man who accompanied him, and on the hat of a gentleman, who, in attempting to brush it off, saw it extend itself over the greater part of his hat; and that at Williamstown, Vermont, it was observed by a company of fourteen persons, as they were returning from a religious meeting, on horses, bushes, fences, logs, and on each other. In one instance a quantity of logs and brush appeared perfectly luminous. The preacher broke off several boughs, on the ends of which the fluid rested. In several cases when he presented his hand, the fluid hissed with the appearance and noise of the electric spark. At this time, it snowed very fast, at the rate, as was supposed, of 6 inches in an hour; the lightning was frequent, and the thunder heavy. At Williamstown it rained principally, and also at Brattleborough. But from Adams through Wilmington to Brattleborough it snowed with great rapidity.

A still more particular account of these electrical appearances was communicated to me in a letter from a young gentleman,† a member of Union college, Schenectady, who was at this time residing at Andover, Vermont, and was a witness of what he relates. The following is his statement.

"In the evening of the 17th of January 1817, as I was returning from a neighbour's house in company with another young man, between the hours of ten and eleven, we observed that the

* Professor Dewey of Williams College. † Joel Manning, jun.

snow was falling very fast, and that there were frequent flashes of lightning. The singularity of the last-mentioned appearance, at that season of the year, particularly attracted our attention. After noticing it for some minutes, we passed on, and when at the distance of a few rods, we observed an appearance of light or fire upon the tops of the stakes in the fence and bushes by the side of the way. The novelty of these appearances rendered them, in our opinion, worthy of particular attention. And the probability of their soon disappearing made us more anxious that there might be others to witness the same fact. We accordingly called the people who were in a neighbouring house; but instead of the lights disappearing, they seemed to shine with additional brightness, and to appear where they were unobserved before; on our hats, on our hair, when our heads were uncovered, and on a woollen mitten, when held above our heads. These lights appeared on all substances, which extended to any considerable distance above the surface of the ground, and approached to a point; but they had not all the same form. For the most part the light appeared like a spark or star, but in some instances it resembled a blaze, in form of an inverted cone of about two inches in height, and three fourths of an inch in diameter at the base. These blazes emitted a hissing sound resembling that of the water in a tea-kettle just before it boils, which could be heard distinctly at the distance of six or eight feet. After viewing them for some time, we proceeded homewards, and in passing over ground somewhat higher, found this appearance to increase, so that our hats and shoulders were almost covered with the lights; and when we spit, the small particles of saliva, when at a little distance from the mouth, assumed a shining appearance. After going about fifty or sixty rods, we came to the side of a lot of

standing timber, where these appearances were not to be seen, except on the tops of some high apple trees on the other side of the road. The falling of the snow, and the height prevented our ascertaining whether there were lights on the tops of the forest trees. We did not leave the standing timber, until we had come down on low ground, where we saw no lights until we got home. About twelve o'clock, we returned to the place where we first saw the lights. The snow was yet falling very fast, and there appeared to be still more of the before-mentioned lights; but we saw no blazes.

"Where these lights were seen, was a tongue of elevated land, extending from the north, down between two quite small branches of Williams' river. The whole length of way we travelled that evening was about a mile. Where we first saw the lights, was very near the top of this ridge of land, descending steeply to the east, for about a hundred rods to a small stream, not sufficient to turn a mill, and to the west, with a more gradual descent, for a mile to another stream a little larger. There are no very considerable streams in this vicinity.

"The wind was not strong, but a light breeze blowing from the northeast, and the weather was not so cold as usual for that season of the year. The flashes of lightning, when we first observed them, which was a little past ten o'clock, were very frequent, four or five in a minute; but the claps of thunder were seldom, and these appeared to be at a distance, and not heavy. But the flashes of lightning soon became less frequent, more vivid and more usually attended with thunder. About twelve o'clock, there was a number of very sharp flashes of lightning, attended with quite heavy thunder.

"The above-mentioned blazes of light were precisely like the appearance upon a wire, in a dark room, over-charged with positive electricity. All that I can say of the circumstances necessary to produce these blazes is, that we observed them on stakes in the fence higher than other substances near them, and extending to a considerable depth in the ground, and when they were removed, the blazes disppeared, and were succeeded by stars."

Appearances similar to the above, it is said, were observed a few years ago at Colchester, Connecticut, and on the 10th of March 1817, at Shelburn, Hampshire County, Ms. During a thunder storm at the latter place, a light appeared on a well-pole when elevated. Upon its being drawn down, the light gradually diminished, and at length entirely vanished. When the pole was raised again, it reappeared.

XII.

Observationes Carpologicæ in Kamelliam et Theam.

a **W. D. PECK, *A. M. A. A.***

Soc. Hist. et Agric. Mass. Socio; Hist. Nat. Prof.

Plantarum affinitas, quanquam a floris structurâ habituque universali, felicitèr saepè, hariolari licet; est veruntamen in fructûs naturâ et compagine quaerenda, et demum confirmanda.

In plantis dijudicandis, e regionibus longè dissitis, quarum fructus nec peregrinatores legerunt, nec in hortis Europaeis maturantur, judicio ex flore etc. contenti esse cogimur; est his Kamellia* annumeranda.

Anni Salutis 1811 autumno, arbusculam Kamelliae japonicae recepi, non optimè vigentem, terrae verò recentiori immissa, vigorem recuperavit et post duos vel tres annos laetè floruit, seminaque dedit matura, quae terrae mendata optimè propullularunt. In viridario semper hospitata, foris nunquam solis ardoribus, nec ventorum violentiae fuit objecta, et nunc temporis, altitudinem duodecim pedum, et diametrum baseös trunci trium circiter pollicarum est adepta. Quamvis autem semina probè matura protulit, at fructum tamen rarissimè edidit numeris omnibus absolutum.

* In honorem nominata Georgii Josephi Kamel, Theologi, Missionarii in Insulis Phillipinis; "cujus sunt multa bona in Transact. Philosophicis;" et ad consilium cel. Dryandri K, loco C scribo, utpotè magis conforme autographiae Botanici tam benè meriti. Vide Transactions of the Royal Society, Vol. 23—27.

De hoc fructu omnia quae usque ad huc scivimus ex fontibus Kœmpferianis hausta videntur; sed nec descriptio a cel. peregrinatore adhibita, nec ejus figura specimini meo quadrant. Semina ipsa matura capsulas existimasse videtur et abortiva pro veris seminibus à prioribus prodeuntibus; mirâ sane incuriâ tam oculati observatoris. Sic in ill. Linn. Gen. Plant. editioni 6to. Capsula continere dicitur *Nucleos* tot, quot striae capsulae, *subrotundos,* seminibus minoribus saepè *repletos:* et in edit. cel. Schreberi vorba sunt, *Nuclei* tot, quot loculamenta, *subrotundi,* seminibus minoribus saepè *repleti;* in edit. 3tia verò Nuclei tot, quot striae *capsulae subrotundae,* seminibus minoribus saepè *repletae;* sed haec etiam perperam innuit loculamenta polysperma. Mihi ergo dubitanti an ab alio factum fuerit, ortâ occasione, descriptionem adcuratiorem in medio proferre, me debuisse putavi.

Capsula Kamelliae et Theae sulcis tribus longitudinalibus est notata, in Theae magis profundis; dissepimenta tria, intus sulcis exactè opposita; aperiente capsulâ in valvulas tres, lentè et concinnè satis, laceratur; sed absque omni suturae vestigio; a pressione seminum, dissepimenta in medio membranacea fermè evadunt, et sub dehiscentia lacerata, columellam acutè triangularem relinquunt. Seminibus integumenta tria, testa nempe; intermedium lamelloso spongiosum, semine diu satis aquâ tepidâ macerato, testae adhaerens; et intimum tenuissimum adhaerens embrioni. Si autem cautè auferatur testa semine sicco, integumentum intermedium facilè in binas partes findatur, adeòque in visum prodit plexus vasculosa per substantiam lamellosam intimè et copiosè dispersa.

Dum perpendi distributionem vasorum, quibus scatet hoc integumentum, non potui quin obitèr in mentem veniret ἀναλογία quae-

dam cum tunicâ Chorio in mammaliis, quae numero ingenti vasorum sanguiferorum abundat.

Ratio distributionis in quâ evolvitur chorda pistillaris mirè et maximè variat in seminibus familiâ diversis. In Sapotis, inter integumenta pulchrè dispanditur; in Aurantii seminibus e raphis vaginâ emergens statim in chalazae superficiem explicatur et exemplum prorsus insigne praebent semina Cassuarinae equisetifoliae, quarum testae tenui maximus trachearum numerus substernitur.

Liquor polline contentus, stigmatis humore mistus et a stigmate resorptus, his vasis, fortasse, pervehitur ad eorum punctum convergentiae, ibique amnii sacculum sub micropylo penetrat. Hujus verò et aliorum plurium indagatio, ad physiologiam attinet, et botanico, microscopii usui frequentiori adsueto, qui otio fruitur, qui oculo exercito manuque gaudet expertâ, multa campus hic offert tam metitu digna, quam observatu jucunda.

Kamellia japonica.

Calyx pentaphyllus squamis suffultus, deciduus. Corolla petala quinque coronulae staminum accreta. Stamina numerosa basi in coronulam hypogynam coalita. Ovarium superum triloculare, ovulis in singulo loculo quaternis. Stylus unicus, ex tribus conflatus, apice trifidus. Capsula trilocularis, loculis tetraspermis.

Induviae nullae.

Pericarpium. Capsula supera coriacea, crassiuscula, obpyriformi-globosa, punctis callosis sparsis aspersa; sulcis tribus haud profundis notata; trilocularis, trivalvis, dissepimentis intus sulcis oppositis.

Placentatio. Chordae pistillares tres prope angulos columellae apicis penetrantes, quarum unaquaeque quatuor praebet chor-

dulas, et harum binas utrinque in cellulos vicinos prope apicem, binas prope medium columellae immittit, per eminentiam hilo excavato adaptatam : his semina sessilia adhaerent.

Semina. Capsulâ perfectâ, in singulo loculo quaterna, saepe verò unum, duo, vel tria abortiunt ; quam plurimum itaque formâ variant.

Forma. Pro numero loculorum fertilium et seminum maturorum in loculis, sunt semina nunc hinc convexa indè angulata ; nunc semielliptica ; nunc ovalia ventre planiuscula, abortivorum figuris semper testae impressis notata, spadicea, glabra, a striulis minutis ad micropylum vergentibus sericeo-nitida. *Hilum* majusculum, ad superiorem partem seminis (in situ) subovatum, concavum, *Omphalodio* circa medium perforatum, *Micropylus* rimula obliquè infra omphalodium in ipso margine testae ad hilum, vel nonnunquam tantillum a margine remotus, ut in fig. 7.

Integumentum triplex, *exterius* crustaceum, fragile, supra hilum (sem. in situ) crassius et canali adscendenti perforatus pro transitu vasorum umbilicalium ; ad micropylum tenuius et intus excavatus pro receptione prominentiae radiculae ; *intermedium* testae adhaerens, crassiusculum, lamelloso-subspongiosum, vasis umbilicalibus scatens, quorum truncus primùm versus dorsum per canalem ascendit, ad dorsum seminis descendit, et fruticis ramorum instar dividitur, deinde adscendit ramulis ad micropylum convergentibus ; integ. *intimum* membranaceum, tenuissimum, embryoni adhaerens.

Perispermum Nullum.

Embryo semini conformis in recenti fructu albidus. *Cotyledones* crassae, plano-convexae vel plano-angulatae pro formâ seminis, amygdalino-carnosae, oleosae. *Radicula* brevis, adscendenti-centripeta, plumula diphylla.

Thea Bohea.

Calyx pentaphyllus, persistens. Corolla. Petala quinque. Stamina numerosa hypogyna. Ovarium superum, globosum triloculare, ovulis in singulo loculo quaternis. Stylus unicus, ex tribus conflatus, supernè trifidus. Capsula trilocularis, loculis tetraspermis, duo vel tria semina ferè semper abortiva.

Induviae Calycis foliola quinque persistentia.

Pericarp. Capsula, subglobosa, trifariam tumida et quasi ex portionibus globorum trium formata, profundè trisulcata, umbilicato-depressa ; cetera ut in Kamelliâ.

Placentatio. }
Dehiscentia. } ut in Kamelliâ.

Seminum. Forma rotundior et Hilum majus, cetera singula, eadem ac in Kamelliâ.

Observatio. Staminum basi coadunationis caussâ, Kamelliam inter Monadelphias locavit ill. Linnæus ; longè verò secus est hæc staminum coalitio, et aliâ omnino lege constituta, ac in Malvaceis ; quoniam in his Corolla quàm plenissima sit, tota simul discutitur; in Kamelliæ autem, floribus plenis, petala gradatim et seorsim decidunt. In hac staminum structurâ et Capsula nuda tantùm differt a Theâ : fructûs compagine partium, materiei indole et aliis omnibus tam inter se similes sunt hæc plantæ, sicuti jàmpridèm suspicavit Petiverius, ut ne vix quidèm genere sejungi queant.

Explicatio Tabulæ 1^{mae}.

Kamellia japonica.

Fig. 1. Capsula matura plena magnitudine naturali.

2. Eadem paululum aperta, cum apice ramuli.

3. Eadem aperta cum seminibus in situ. a. semina duo abortiva, b. cicatrix rhomboidea quâ valvula apici columellae adhaesis-

set et in quâ, c. vestigium chordae pistillaris ad apicem columellae transiens, in visu cadit.

4. Capsula siccata maximè expansa, placentationem seminum exhibens, a. columella reliquiis dissipimentorum laceratorum b. trialata; c. pori per quas chordae pistillares transgrediunt ad d. d. quà columellam intrant; c. c. puncta placentationis et pori, e quibus vasa umbilicalia omphalodio immittuntur.

5. Semen a latere ventris visum, quod unicum fuit in loculo, impressionibus tribus a. a. a. seminum abortivorum signatum; b. hilum, c. omphalodium, d. micropylus.

6. Semina quae duo fuerunt in loculo, cum abortivis duobus a. a. in situ.

7. Semina quae tria in loculo, in situ, quartum defuit; in imo micropylus a hilo tantillum remotus.

8. Semina perfecta quatuor in situ quae loculum implerunt numero naturali.

9. Semen dimidio integumentorum orbum, a. cotyledon, b. corculum radicula supera, plumulâ diphyllâ.

10. Corculum serorsim magnitudine auctum.

11. Testa seminis siccati intus visa a latere dorsi, exhibens vasa umbilicalia intra testam et per integumentum intermedium pulchrè distributa.

12. Testae interior a latere ventris, vasa eadem exhibens in micropylum convergentia.

Thea Bohea.

I. Capsula matura magnitudine naturali, seminibus tribus perfectis fœta, Columellae apex scrobiculis angularibus tribus insculptis, ad apices valvularum capsulae recipiendos.

II. Semen maturum quod in cellula fuit solitarium, cum hilo,

omphalodio et micropylo ut in Kamelliae seminibus, impressionibus tribus abortivorum notatum.

III. Embryo denudatus, regione radiculae prominente ad locum micropyli.

IV. Cotyledon cum corculo in situ.

V. Corculum seorsim, magnitudine auctum.

XIII.

Remarks on Doctor Stewart's formula, for computing the motion of the Moon's Apsides, as given in the Supplement to the Encyclopedia Brittanica.

BY NATHANIEL BOWDITCH, LL. D.

A FEW years after Doctor Matthew Stewart had published his computation of the sun's distance from the earth,* by means of the motion of the moon's apsides, a communication† was made to the Royal Society of London by Bishop Horsley in support of the accuracy of that calculation. The opposite ground was taken by Mr. Dawson and afterwards by Mr. Landen,‡ who clearly proved that several small quantities, neglected by Doctor Stewart (in order to simplify the *geometrical* investigation), would produce a very great effect on his estimate of the sun's distance. Moreover Mr. Landen expressed some *doubts* of the accuracy of the principles assumed by Doctor Stewart, and objected among other things to the total neglect of the part of the sun's disturbing force in *the direction of the tangent of the moon's orbit,* in finding the fundamental theorem to express the motion of the moon's apsides. Mr. Landen, however, on account of the great difficulty of the subject, made *no*

* The distance of the Sun from the Earth determined by the Theory of Gravity etc. Edinburgh, 1763.

† Published in the Transactions of the Royal Society of London for the year 1767.

‡ In his "Animadversions on Doctor Stewart's computation of the Sun's Distance, etc. London, 1771.

calculation to ascertain whether this neglected force did in fact produce any effect in the result. The subject was again brought before the public in the interesting Biography* of Dr. Stewart by Professor Playfair, who, after noticing the animadversions of Mr. Landen and acknowledging that in some of the minor points there were defects in the calculation affecting considerably the *computed* distance of the sun, alludes to the other objections, and finally concludes that the method of finding "the relation between the "disturbing force of the sun and the motion of the apses of the lu-"nar orbit, instead of being liable to objection, is deserving of the "greatest praise, since it resolves by geometry alone, a problem "which had eluded the efforts of some of the greatest mathemati-"ciàns,† even when they availed themselves of the utmost re-"sources of the integral calculus."

This opinion of the accuracy of the method is adopted by Doctor Hutton in his Mathematical Dictionary,‡ and by La Lande in his Astronomy,§ where the work is mentioned in terms of approbation; as it is also in the elegant article on Physical Astronomy, published in 1816 in the last Supplement to the Encyclopedia Brittanica, and in other late publications.** In that article of the En-

* Printed in the year 1788, in the Historical Part of the Transactions of the Royal Society of Edinburgh, Vol. I. p. 69.

† Alluding more particularly to Euler, D'Alembert and Clairaut, whose first calculations made the motion of the moon's apsides only half of what it was found to be by observation.

‡ First edition. London, 1795, Article *Stewart*.

§ Third edition. Paris, 1792.

** The subject has been brought before the public within a few years in periodical journals of great celebrity. Thus in the Edinburgh Review, Vol. XI. p. 280, published in 1809, it is observed, that "the late Doctor Matthew Stewart also "treated the same subject [the motion of the apsides] *with singular skill and suc-"cess* in his essay on the sun's distance."

cyclopedia is given the following analytical expression of the fundamental theorem of Doctor Stewart's calculation, noticed in terms indicating a full belief in its accuracy. "In his [Doctor Stewart's] "Mathematical and Physical Tracts, he has *demonstrated* this re- "markable theorem. Let r be the radius of the moon's orbit, "supposing it to be a circle, and the moon to be acted upon only "by F, her gravity to the earth. If the mean disturbing force by "which the sun diminishes the moon's gravity be f, then will ..... "the angle described by the radius vector from one apsis to the same "apsis be $360° \times \left(\frac{F - 3f}{F - 5f}\right)^{\frac{1}{2}}$. This proportion *which is demon- "strated by Doctor Stewart* in the fourth of his tracts, in a man- "ner somewhat prolix, on account of his rigid adherance to the "manner of ancient geometry, but in *a way perfectly clear and "elementary,* is employed by him to deduce the mean disturbing "force from the motion of the apsides, as ascertained by observa- "tion."

After taking this historical view of the subject, which seemed to be necessary in order to form a correct judgment of the present state of the question, it may be remarked, that these late opinions of eminent mathematicians in favour of the accuracy of this method of computing the motion of the Moon's apsides being unaccompanied with any additional illustration or proof, do not remove the objections which have been raised, that *the neglect of the tangential force* and other peculiarities of the method might possibly affect the result; it therefore becomes a subject worthy of examination to ascertain whether this fundamental theorem expresses in an approximative form, the mean motion of the apsides,

supposing with the author the excentricity to be very small, or the orbit nearly circular.

There is now no great difficulty in settling this point by means of the analytical expression of the motion of the apsides given by La Place in his excellent Lunar Theory, published in the third volume of his *Mécanique Céleste,* where however the approximation is carried on to a higher order of the powers and products of the excentricities and disturbing forces, than is absolutely necessary for the present purpose. Upon applying this method, I found that Doctor Stewart's formula was very far from being so correct as had been supposed by most of the writers above mentioned. On the contrary, it appears to be essentially defective. *The first and most important term of the series is double its true value;* and the whole formula gives an accurate *numerical* result only when the motions of the primary planet and satellite have a certain proportion to each other, which (by a remarkable coincidence) happens to be the case (nearly) with the moon and earth; but the same formula would not answer if the moon's distance from the earth was much greater, or much less, than it now is; and it would require but a very small decrease of the moon's mean distance from the earth, to render the sun's distance *infinite* when computed according to Doctor Stewart's directions, so that this method would have failed, if it had been applied to other cases, as for instance Jupiter's Satellites.* To prove this I shall now proceed to reduce the formula given by La Place to the case computed by Doctor Stewart.

The orbits being supposed nearly circular and situated in the

* Neglecting the mutual action of the satellites, and the effect of the oblateness of the primary planet.

plane of the ecliptic, we may neglect the third powers of the excentricities e, e', of the orbits of the moon and earth, and the terms depending on γ, the tangent of the inclination of the lunar orbit to the ecliptic. Then by La Place's notation, v represents the angular motion of the moon round the earth in the time t; m the ratio of the periodic time of the revolution of the moon about the earth to that of the earth about the sun; $(1-c)v$ the motion of the moon's apsides, and by page 213, vol. iii. *Mécanique Céleste* $c=\sqrt{1-p}$; p being the coefficient of $-e\,.\cos(cv-\varpi)$ in the equation (L′) page 209 of the same volume multiplied by $\frac{a}{1+ee}$, or by a, because we neglect terms of the order e^3; so that if we put, as in page 227, of the same work $\overline{m}^2 \,.\, \frac{a}{a_{,}} = m^2$, this value of p will become, by neglecting terms of the fifth order in m,

$$p=\tfrac{3}{4}m^2 . \{2-20\,A_2^{(0)}+\frac{\{(1+6m+c).(1-m)+7+(2-2m-c)^2\}}{1-m}.A_1^{(1)}\} \quad (1)$$

the values of $A_2^{(0)}$, $A_1^{(1)}$ being determined by the following equations given in page 215 of the same volume, in which we have neglected e^2, e'^2, and some of the terms producing m^5 in p.

$$0=\{1-4(1-m)^2\}.A_2^{(0)}+\tfrac{3}{2}m^2.\{1+\frac{1}{1-m}-A_2^{0}\} \quad (2)$$

$$0=\{1-(2-2m-c)^2\}.A_1^{(1)}+3m^2.\{\tfrac{1}{4}c-\frac{(3+4m)}{4}+\frac{1-c^2}{4.(1-m)})-\frac{2(1+m)}{2-2m-c}-\tfrac{1}{2}A_1^{1)}+A_2^{(0)}\} \quad (3)$$

If we neglect the terms of $A_2^{(0)}$ producing m^5 in p, the equation (2) will give

$$A_2^{(0)}=m^2. \quad (4)$$

The first term of p in the equation (1) is the most important, and, if we retain only this term we shall have $p=\frac{3}{2}m^2$, and $c=\sqrt{1-p}=1-\frac{3}{4}m^2$, nearly. Substituting this in the equation (3), we shall get for $A_1^{(1)}$ the following value, neglecting terms of the order m^3, which produce m^5 in p,

$$A_1^{(1)} = \tfrac{15}{8}\, m + \tfrac{273}{32}\, m^2. \qquad (5)$$

Substituting this in the equation (1), which may be put under a form $p = \frac{3}{4} m^2 . \{2 - 20\, A_2^{(1)} + 10\,(1 + m) . A_1^{(1)}\}$ it becomes

$$p = \tfrac{3}{2} m^2 \{1 + \tfrac{75}{8}\, m + \tfrac{1345}{32}\, m^2\} \qquad (6)$$

Now the mean motion of the moon from apsis to apsis being $\frac{360°}{c} = 360° . (1 - p)^{-\frac{1}{2}} = 360°\,(1 + \frac{1}{2} p + \frac{3}{8} p^2 + \text{\&c.})$ the motion of the apsides in the same time will be $360°\,(\frac{1}{2} p + \frac{3}{8} p^2 + \text{\&c.})$, and by using the preceding value of p it becomes*

$$\tfrac{3}{4} m^2 . \{1 + \tfrac{75}{8}\, m + \tfrac{1381}{32}\, m^2 . \} . 360° \qquad (7)$$

If we substitute the value of $m = 0.0748013$, corresponding to to the moon, the three terms of this formula will become respectively 5439″, 3814″, 1313″, whose sum is 10566″ = 2° 56′ 6″, which differs a few minutes from observation 3° 4′ 7½″ on account of the neglected terms. The first of these numbers 5439″ is nearly equal to the sum of the two last 5127″, so that the motion is nearly doubled by noticing these two terms. This was not done fully by D'Alembert, Euler and Clairaut in their first approximations towards a correct lunar theory, so that they then made the motion only *half* its real value.† The term $A_1^{(0)}$ seemed

* The two first terms of this expression agree with what I had computed several years ago, by following Clauraut's method, published in the *Memoires de l'Academie des Sciences, &c. Paris*, 1748.

† The same may be observed of Newton's method given in the *Principia* Lib. 1. Prop. xiv. cor. 2. Where the motion of the moon from Apogee to Perigee is put equal to $180° \sqrt{\frac{1 - c}{1 - 4c}}$, c being equal to $\frac{1}{2} m^2$ of the above notation. Substituting this value, and developing the expression according to the powers of m^2, the motion of the apsides in one revolution from apogee to apogee would be expressed by $\frac{3}{4} m^2 . [1 + \frac{13}{8} m^2] . 360°$ of which the first term agrees with the formula (7), and is therefore *correct*, but the other term is inaccurate.

to be of the order m^2, but it was increased by a divisor of the order m, with which it was affected, when its value was calculated by means of the equation (3); this made it too important to be neglected, as had been supposed at first might be done.

Doctor Stewart's theorem, expressed as above in an analytical form makes the motion of the apsides in one anomalistic revolution equal to $360^\circ \left(\frac{F-3f}{F-5f}\right)^{\frac{3}{2}} - 360^\circ$, or by development according to the powers of $\frac{f}{F}$

$$\left\{3 \cdot \frac{f}{F} + \frac{33}{2} \cdot \frac{f^2}{F^2} + \&c. \right\} . 360^\circ \qquad (8)$$

and if we use the value $\frac{f}{F} = \frac{1}{2} m^2$, as it is given by Doctor Stewart in Prop. 19 of his fourth Tract,* it becomes

$$\tfrac{3}{4} m^2 . \{2 + \tfrac{11}{2} . m^2 . \} . 360^\circ. \qquad (9)$$

which differs very much from that computed in formula (7). For by comparing the two expressions (7), (9), we find, that if m is very small, Doctor Stewart's theorem makes the motion *nearly double its true value.* If m is nearly equal to 0.08 . . . . , the two *numerical* values become equal; but if m exceeds that quantity, his theorem makes the motion *too small.* The limit 0.08 . . . . , would be altered a little by the introduction of the terms we have neglected. This limit is very nearly equal to the value of m corresponding to the moon's orbit, and from this accidental circum-

* This is given as an *approximation* towards the true value, and it agrees nearly with Mr. Landen's estimate in page 9 of his Animadversions. The terms of a higher order in m, which were neglected by Doctor Stewart, would not affect the first term of formula (9), it was therefore unnecessary to correct this value of $\frac{f}{F}$, since the error of that formula is proved by the error of its *first* term, as well as it could be by the comparison of the whole series.

stance it happens that the *numerical* values of the formulas (7), (9) become nearly equal in *this particular case*, although their *general analytical* values are essentially different from each other. I have not thought it necessary to enter into a discussion of other parts of Doctor Stewart's work, since this defect in the most important theorem *makes the method wholly fail:* but before closing this paper, it may be proper to demonstrate what was remarked above, that by following *implicitly* his method, the sun's computed distance would have been *infinite*, if the moon had been situated a little nearer to the earth.

I shall refer to Prop 11, of Doctor Stewart's essay on the sun's distance, using the figure corresponding thereto. The two chief numbers mentioned in the first part of that Proposition are 178.725 and 357.43365, which for perspicuity I shall denote by a and b respectively. Then by going over the calculation of Prop. 11, precisely in the same manner as Doctor Stewart has done, it will be found that AB : Bs : : 178.20095 $(= 4a + 3b)$: 0.01635 $(= 2a - b)$, so that if m was assumed of such a value as to make $2a - b = 0$, the quantity Bs, which represents the *versed sine* of the arch Bv would be *nothing*, consequently the corresponding *sine vs* would be *nothing*, and since by construction $\mathrm{BD} = \frac{3}{2} \cdot \mathrm{AB}$, the ratio BD to $v\,s$ would be *infinite*. But it is said (in page 58 of that essay) that the ratio of the mean distance of the sun from the earth to the mean distance of the moon from the earth is *greater* than that of $\frac{\mathrm{BD}}{vs}$; hence it would follow, that the sun's distance from the earth would be *greater than infinite* if $2a - b = 0$. Now this equation could be easily satisfied by decreasing a little the value of m. For, by page 5[illegible] of the same work, $a = \frac{1}{m^2}$, and if we suppose the motion of the moon from

apogee to apogee to be represented by $360°.\ (1+n)^{\frac{3}{2}}$, we should have by Prop. 9. of the same work, $b=\frac{\mathrm{TA}}{\mathrm{A}m}=\frac{2}{n}+5$, so that the preceding equation would become $\frac{2}{m^2}-\frac{2}{n}-5=0$. Now, when m is extremely small, the motion of the moon from apogee to apogee is by formula (7) nearly equal to $360°\ (1+\frac{3}{4}m^2)$, which being put equal to the assumed value $360°\ (1+n)^{\frac{3}{2}}$, gives $n=\frac{1}{2}m^2$ nearly; and then the left hand side of the preceding expression would become $-\frac{2}{m^2}-5$, which is *negative*, whereas it was found to be *positive* for the value $m=0{,}0748013$ corresponding to the present situation of the moon, consequently there must be a value of m less than 0,0748013, that would satisfy the proposed equation $\frac{2}{m^2}-\frac{2}{n}-5=0$; and a slight attention to the subject will show that no great change in the present value of m would be necessary to produce this effect, and thus fall upon the case which would make the *computed* distance of the sun from the earth infinite. Less values of m would be *impossible* in this method of calculation, because the *versed sine* $v\,s$ would be *negative*. It was thought unnecessary to make this part of the calculation with any greater degree of precision, on account of the terms of the order m^5 neglected in formula (7), upon which the value of n depends.

I shall close these observations with the remark, that the mistake here noticed in Doctor Stewart's tracts may be attributed wholly to the use of the *geometrical* method of investigation to which that eminent geometrician was so very much attached—the failure of so distinguished a mathematician shows how extremely difficult it is

to apply this method with success to complicated problems requiring such great accuracy. In fact there are very few questions in the higher branches of Physical Astronomy where the ancient geometry can be used with much advantage. The most remarkable instance of its application to such problems is that of Maclaurin, whose computation of the attraction of an ellipsiod, stands unrivalled for elegance and simplicity, and it loses none of these qualities in the masterly hand of Mr. Ivory, by the extension he has given to it, in the excellent article on the Attraction of Spheroids in the same Supplement to the Encyclopedia Brittanica.

XIV.

Description of several Halos and Parhelia, observed at Brunswick, Maine.

BY PARKER CLEAVELAND,

PROFESSOR OF MATH. AND NAT. PHIL. IN BOWDOIN COLLEGE.

If it is always important, that notices of uncommon events should be preserved on the records of Philosophical Societies, it is peculiarly so, when the causes of such events have not been investigated in a satisfactory manner. I therefore transmit to the Academy a description and figure of several remarkable Halos and Parhelia, which were observed at Bowdoin College, Maine, on the 17th March, 1815, and the 15th April, 1818.

1. During the morning of the 17th March, 1815, the atmosphere was entirely free from clouds. That Parhelion, which eventually proved to be the brightest, was observed as early as 7 o'cl. A. M; about 20 minutes before 10 o'cl. A. M. all the Halos and Parhelia were distinctly visible, and, for nearly 45 minutes, continued to present an appearance uncommonly striking and beautiful. The phenomena gradually disappeared, in consequence of the condensation of vapor and the actual formation of clouds; and about 2 o'cl. P. M. snow began to fall very copiously.

I did not observe the commencement of these phenomena; but I am very fortunate in being able to avail myself of the observations of Henry Putnam Esq. of this town, who very carefully and attentively observed all the Halos and Parhelia, during the whole time of their appearance.

Circumstances prevented the use of a sextant in measuring diameters, distances, &c. but the circles with their intersections &c. were, in general, so perfectly distinct, that the annexed figure cannot, I think, be materially incorrect in regard to proportions &c.

Explanation of figure 1.

S, the true sun.

s, s, two parhelia, irised and very bright; but their centres were nearly of the same color, as the true sun.

d, d, two white parhelia, very distinct.

I, a remarkably bright and beautiful parhelion, irised, and somewhat spreading, in consequence of the apparent contact of the two halos.

B, a very vivid and irised contact of the two halos; but it did not seem to be a parhelion.

BOIN, an irised halo, having the true sun for its centre; yellow and red were the predominant colors.

ABC, a semicircular arc of a halo, touching the preceding at B; it was irised, but the yellow was less intense, than in BOIN.

DFSE, a bright, well defined halo, perfectly *white.*

DH and DG, two arcs of halos, intersecting at D, and extending to about H and G, irised, but rather faint.

K, a small arc of an irised halo, distinct, but not bright.

L, another small arc, irised and much brighter, than the arc K.

x y, a small irised arc convex toward BOIN, and touching it at I.

MP, an arc somewhat less than a semicircle, and perfectly resembling a rainbow; it was nearly east from the place of observation.

Remarks on figure 1.

It is much to be regretted, that circumstances prevented the use of instruments on this occasion. The preceding figure, projected by the eye, is designed for about 15 or 20 minutes past 10 o'cl. A. M; at which time all the halos and parhelia were visible, the altitude of the sun being somewhat less than 40°. The general appearance had, however, remained nearly the same for at least 30 minutes previous to this time.

The parhelia *s, s*, were apparently about 45° from the sun, and their size nearly the same, as that of the sun.

The parhelia *d, d*, were, by estimation, about 90° from *s, s*, and their size nearly the same; their light was mild, and the eye dwelt on them with peculiar pleasure.

The *white* halo DFSE was not far from 90° in diameter; it passed through the sun's disc, parallel to the horizon, and apparently had the zenith for its centre; if so, its real diameter must have varied, as its radius would be the sun's zenith distance, which was constantly diminishing.

The centre of BOIN was the true sun, and the diameter of this halo was between 44° and 50°.

The centre of ABC is supposed to be at the parhelion I; some observers thought, that this halo was elliptical; but this appearance was probably an optical deception, arising from the relative size and position of the halo in regard to BOIN.

The arcs K and L very probably had the parhelion I for their centre, one of them passing through Z, and the other, perhaps, a tangent to the white halo at D; but it is impossible to determine this point.

The arcs DH and DG seemed to tend toward the parhelia *s, s*; if so, their centres, in the projection, would be at *r* and *r* in lines drawn from the true sun through the parhelia *s, s*.

In the arc MP, the point P was a few degrees above the horizon.

Concerning the planes of the halos, little can be said with certainty. The plane of DFSE was evidently parallel to the horizon, and formed, at its lower side, an obtuse angle with the plane of the halo BOIN; the plane of ABC appeared to be coincident with that of BOIN.

A small cloud passed between S and B, and became very bright and irised.

In the phenomena just described, there were 9 halos or arcs of halos, and 5 parhelia or mocksuns; and, if the preceding remarks are correct, there were 7 different centres for the halos. I have already ascertained, that these, or rather similar halos &c. were observed, more or less distinctly, for an extent of at least 45 miles in the direction of the meridian. This is probably a very uncommon circumstance.*

The preceding figure agrees in part with figures of similar phenomena observed by Scheiner, at Rome, in 1629; by Hevelius, at Sedan, in 1661; by the Philos. Society, at Paris, in 1667; by Mr. Gray, at Canterbury, Eng. in 1699 &c. But it is more complex than most of them, and contains some additional halos.

* Since this paper was written, I have been informed, that similar appearances were observed at Boston, on the morning of the same day.

Notice of the weather.

The morning of this day was cloudless, with the wind blowing from N. W; but, during the phenomena, the vapor in the air was condensed with unusual rapidity in the south. About 30 minutes after 10 o'cl. the southern part of the halo BOIN began to be obscured by clouds; and about 2 o'cl. P. M. snow began to descend with the wind blowing from the S. E. The form of this snow was rather uncommon; it was that of very long and slender spicula or prisms.

Two days previous to this phenomenon, rain had fallen with a south wind; but the day, immediately preceding the 17th, was fair with a N. W. wind, and so cold, that the maximum of heat was only 31°. Indeed on the 17th, the thermometer rose no higher, than 31°; and the following day was cloudy and cold with the wind from N. W. During the nights of the 21st and 22d of March, the thermometer descended a little below zero, a degree of cold very uncommon at that season. From the 17th of March to the 14th of April, there were eight distinct falls of snow at Brunswick.

B. Vaughan esq. of Hallowell, repeatedly observed, during the month of March, that, in the region, where the sun was shining, the atmosphere exhibited an unusual aspect. The appearance about the sun seemed to be such, as would result from covering the sky with an extremely thin semitransparent mist, composed of black and white vapors, illuminated from within, and, at the same time, coated without by a transparent, silvery varnish. The black tint was once or twice very conspicuous.

2. Another phenomenon of the same kind was observed April 15, 1818.

Explanation of figure 2.

S the true sun at an altitude of about 38°.

s, s two parhelia, irised and bright, about 45° from the sun.

d a white parhelion, 90° from the sun.

B contact of two halos, very bright, and beautifully irised; the yellow being peculiarly distinct.

IOBN irised halo, having the sun for its centre, and about 45° in diameter.

ABC irised halo, less than a semicircle, and touching the preceding at B. Its radius appeared to be about 45°.

KZW irised halo, larger than a semicircle, passing through the zenith, concentric with the halo ABC; and evidently corresponding to the arc K, in the halos, observed at Brunswick, March, 1815. Its plane appeared to form an angle with a horizontal plane of about 35°.

SFDE halo, perfectly *white*, passing through the sun's disc, parallel to the horizon, and having the zenith for its centre.

Remarks.

The preceding phenomena were observed from 8h. 15m. to 9h. 15m. A. M. at which time they disappeared, in consequence of the formation of clouds in the south. The wind was blowing strongly from the N. E. The clouds exhibited the form of the cirro-cumulus; and reflected a strong and beautiful light, when passing over the halos. The space, included within the halo IOBN was much darker, than the surrounding parts. On the following morning snow fell in rounded grains.

A single *Halo,* or luminous circle, surrounding the sun, is, by no means, an uncommon occurrence. *Parhelia,* or luminous spots, externally tinged with the colors of the rainbow, sometimes called mocksuns, are also not unfrequently observed in the vicinity of the true sun. But a collection of several Halos, both white and irised, some of which form concentric circles, while others are tangential, or intersect each other, accompanied also with several Parhelia, both white and irised, is a phenomenon, which has been but rarely observed.

Among the most striking and beautiful exhibitions of this kind, are those, which occurred at Rome in 1629, at Sedan in 1661, and at Brunswick in 1815.

There is, indeed, a general resemblance between these phenomena, observed at different times, and in different places. But there is also considerable diversity in the number, diameters, inclinations, and colors of the halos, and in the number, situation, and colors of the parhelia.

Were these striking phenomena more frequent, and their cause better understood, it would be unnecessary to increase the number of descriptions. But, while we are still ignorant of the particular manner, in which Halos and Parhelia are produced, it may be useful to collect additional facts, and preserve them on record. Hereby the attention of Philosophers to this subject may be renewed; and, indeed, the slight modifications, which these phenomena exhibit, may be extremely important in leading to a correct explanation of the phenomena themselves.

Descartes, Gassendi, Dechales, Huyghens, Weidler, Muschenbroeck, Æpinus and others have more or less devoted their attention to the investigation of Halos and Parhelia. All agree in attributing them to the refraction and reflection of light by particles

of *vapor*, or of *ice*, or of *snow*, suspended in the atmosphere. No one, however, has yet been able to point out, in a very satisfactory manner, all those circumstances, which must concur in the production of Halos and Parhelia; or to say why particles of vapor, ice, and snow, which are *so frequently* suspended in the atmosphere, should *so seldom* produce the phenomena, of which we speak.

It is not my intention, in this paper, to offer any remarks on the causes of Halos and Parhelia; but merely to recall the attention of Philosophers to the theory of Huyghens. This theory, the outlines of which were communicated to the Royal Academy of Paris, soon after the year 1667, Dr. Priestly says, "has met with the most favourable and the longest reception."

M. Huyghens supposes the light, in these phenomena, to be refracted and reflected by particles of *ice* and *snow*, suspended in the atmosphere, and existing in the form of very minute globes, and also of small cylinders with hemispherical ends. These globes and cylinders have an *opaque* nucleus at the centre, surrounded by a *transparent* shell; and may, perhaps, consist of particles of soft snow, which have once been thawed on the outside by the heat of the sun. The position of these cylinders may be perpendicular, parallel, or inclined.

M. Huyghens expressed a wish, that, for the entire confirmation of this hypothesis, some of these small cylinders could be observed to fall to the ground, at the time, when Parhelia ceased to appear. Maraldi, Weidler and others have, in fact, observed, that, when Parhelia disappear, snow sometimes falls in the form of *oblong spicula*. Within a short time after the phenomena of this kind, which occurred at Brunswick in March 1815, and April 1818, snow fell very copiously. In the former case, its form was that of

long, slender prisms; and in the latter, of *rounded* grains. But the remark of Muschenbroeck may here be repeated, who says that nothing has been advanced, concerning the cause of Parhelia, more probable, than the hypothesis of Huyghens, except that frozen cylinders or spicula are always found *transparent,* and *never opaque* at the centre.

Brunswick, (Me.) April 15, 1818.

XV.

Outlines of the Mineralogy and Geology of Boston and its vicinity, with a Geological Map.

BY J. F. DANA, M. D. & S. L. DANA, M. D.

COMMUNICATED AUGUST 1818.

TABULAR VIEW

OF THE MINERALS DESCRIBED IN THIS PAPER.

CLASS I.—*EARTHY FOSSILS.*

The minerals in this class are neither reducible to the metallick state, nor volatilizable before the blowpipe; it comprehends two orders, viz.

ORDER I.—*ACIDIFEROUS SUBSTANCES.*

These are composed of an acid united to an earth. The genera are founded on the peculiar earth, and the species on the particular acid.

GENUS I.—*LIME.*

Species I.—Phosphate of Lime.

Subspecies I. Apatite.

II.—Carbonate of Lime.

Subspecies I. Calcareous Spar.

Variety 1. Crystallized.

2. Laminated.

" II. Granular Limestone.

" III. Fibrous Limestone.

" IV. Compact Limestone.

" V. Concreted Carbonate of Lime.

" VI. Brown Spar.

ORDER II.—*NONACIDIFEROUS SUBSTANCES.*

These are composed of earths united with each other; sometimes admitting an acid, alkali, or metallick oxide into their composition. They are grouped according to the similarity of their chymical composition.

†‡ *Silica nearly or quite pure.*

SPECIES I.—Quartz.

Subspecies I. Common Quartz.

Variety 1. Limpid Quartz.

II. Hornstone.

†‡ *Silica, Alumine and an Alkali.*

SPECIES II.—Petrosilex.

III.—Mica.

IV.—Schorl.

†‡ *Silica, Alumine, Lime and an Alkali.*

V.—Feldspar.

†‡ *Silica, Alumine and Lime.*

VI.—Basalt.

VII.—Wacke.

VIII.—Garnet.

IX.—Epidote.

X.—Prehnite.

†‡ *Silica, Lime and Water.*

XI.—Schaalstone.

Subspecies I. Chelmsfordite.

†‡ *Silica, Magnesia and Lime.*

XII.—Tremolite.

Variety 1. Common Tremolite.

2. Fibrous Tremolite.

SPECIES XIII.—Asbestus.

†‡ *Silica, Magnesia, Alumine and Lime.*

XIV.—Hornblende.

Subspecies I. Common Hornblende.

II. Basaltic Hornblende.

III. Actynolite.

†‡ *Silica, Alumine and Magnesia.*

XV.—Steatite.

XVI.—Chlorite.

Subspecies I. Common Chlorite.

II. Chlorite Earth.

†‡ *Silica and Alumine.*

XVII.—Pinite.

XVIII.—Argillaceous Slate.

Variety 1. Argillite.

2. Novaculite.

XIX.—Clay.

Variety 1. Potter's clay.

CLASS II.—*SALINE FOSSILS.*

These are composed of an acid united with an alkali, earth, or a metallick oxide, or two of these; they are sapid, and soluble in water. The genera are founded on the peculiar alkali, earth or metal, and the species on the predominant acid.

GENUS I.—*IRON.*

SPECIES I.—Sulphate of Iron.

CLASS III.—*INFLAMMABLE SUBSTANCES.*

These are either solid, fluid or gasseous; they possess a low specifick gravity; when solid, they are seldom crystalized, generally yield with ease to the knife, and are brittle.

SPECIES I.—Hydrogen gas.

Subspecies I. Carburetted Hydrogen.

II.—Peat

Variety 1. Fibrous Peat

2. Compact Peat.

CLASS IV.—*METALLICK FOSSILS.*

These possess great specifick gravity, being usually five or six times heavier than water. The genera are founded on the predominant metal.

GENUS I.—*COPPER.*

SPECIES I.—Pyritous Copper.

II.—Muriate of Copper.

GENUS II.—*IRON.*

SPECIES I.—Sulphuret of Iron.

II.—Magnetick oxide of Iron.

III.—Micaceous oxide of Iron.

IV.—Ochrey brown oxide of Iron.

V.—Nodular Ironstone.

VI.—Carbonate of Iron.

GENUS III.—*LEAD.*

SPECIES I —Common Sulphuret of Lead.

GENUS IV.—*MANGANESE.*

SPECIES I.—Earthy oxide of Manganese.

GENERAL SYNOPSIS.

CLASS I.—*EARTHY FOSSILS.*

Division i.—Infusible before the blowpipe.

† *Soluble with effervescence in Nitrick and Muriatick acids.*

†‡ *Yield to the knife, do not effervesce.*

†‡† *Scratch glass, do not yield to the knife.*

Division ii.—Fusible before the blowpipe.

§ *Hardness equal or superior to that of common window glass, sometimes yield slightly to the knife.*

§ *Yield to the knife, sometimes feebly scratch glass.*

§ *Yield easily to the knife, and sometimes to the nail.*

§ *Very soft, yield to the nail.*

CLASS II.—*SALINE FOSSILS.*

† *Precipitated from their solution in water by carbonated alkali.*

CLASS III—*INFLAMMABLE SUBSTANCES.*

† *Combustible with flame, leave no residuum.*

†‡ *Combustible with flame, yield a large bulky ash, and a pungent odour.*

CLASS IV.—*METALLICK FOSSILS.*

§ *Assume a metallick form after roasting on charcoal while any thing is dissipated, and subsequent fusion with borax.*

† *Lustre metallick.*

†‡ *Lustre non metallick.*

§ *Not reducible to the metallick state before the blowpipe on charcoal, either with or without borax.*

† *Magnetick after roasting.*

†‡ *Not magnetick after roasting.*

SYNOPTICAL TABLE.

CLASS 1.—*EARTHY FOSSILS.*

Not reducible to the metallick state before the blowpipe, nor volatilizable.

Division i.—Infusible before the plowpipe.

† *Yield to the knife, do not effervesce.*

ORDER I.

SPECIES

Subspecies

I. i.—*Apatite.* Green; in short six-sided prisms, soluble in nitric acid.

†‡ *Soluble with effervescence in Nitrick or Muriatick acid.*

II. i.—*Calcareous Spar.* White; crystallized; fragments rhomboidal.

Var. 1. Crystallized Calcareous Spar.

Var. 2. Laminated Calcareous Spar.

ii.—*Granular Limestone.*—White; grey; fragments indeterminately angular, blunt edged; phosphoresces by heat or friction.

iii.—*Fibrous Limestone.* Snow white; fibrous.

iv.—*Compact Limestone.* Whitish; fracture fine grained.

v.—*Concreted carbonate of Lime.* Whitish; in various imitative forms investing other minerals.

vi.—*Brown Spar.* Crystallized in lenses, and in obtuse rhombs.

ORDER II.

XVII.—*Pinite.* Blackish grey; glistening and resinous; in six-sided prisms; fracture uneven and foliated.

†‡† *Scratch glass, do not yield to the knife.*

SPECIES

SUBSPECIES

I. I.—*Common Quartz.* Shining and vitreous lustre; crystallized in hexagonal prisms; amorphous; splintery; conchoidal.

Var. 1. *Limpid Quartz.* Colourless; transparent; amorphous.

I. II.—*Hornstone.* Grey; dull; splintery; tough; becomes white before the blowpipe.

DIVISION II.—Fusible before the blowpipe.

§ *Hardness equal or superior to that of common window glass, sometimes yields slightly to the knife.*

† *Yields a black glass, or enamel.*

VIII.—*Common Garnet.* Red and brownish red; crystallized in double eight-sided pyramids acuminated by four planes.

XIV. II.—*Basaltick Hornblende.* Black; shining; crystallized in single hexagonal prisms.

†‡ *Yields a white glass or enamel.*

V.—*Feldspar.* Red, black, and white; amorphous, and crystallized in tables and rhombs; lamellar structure.

XI. I.—*Chelmsfordite.* Whitish, greenish; pearly; crystallized in rectangular prisms; phosphorescent by heat.

§ *Yield to the knife, sometimes feebly scratch glass.*

† *Yield a white glass or enamel.*

XII.

Var. 1. *Common Tremolite.* Whitish, greenish; pearly; fibrous, passing to imperfectly foliated.

†‡ *Yield a greenish or blackish grey enamel.*

SPECIES

SUBSPECIES

XVIII.

Var. 2. *Novaculite.* Greyish, greenish; splintery fracture.

XIV. III.—*Actynolite.* **Grey, green; diverging fibrous; foliated; crystallized in imperfect six-sided prisms.**

†‡† *Yield a yellowish glass or enamel.*

X.—*Prehnite.* Green, white; glistening; pearly; fusible into a yellowish frothy glass.

†‡†‡ *Yield a black or dark green glass or enamel.*

IX.—*Epidote.* Green, amorphous and in acicular crystals; fracture splintery, uneven and fascicular diverging.

XIV. I.—***Common Hornblende.* Greenish, blackish; tough; foliated.**

VI.—*Basalt.* Greyish black; dull; faintly glimmering; brittle.

§ *Yield easily to the knife and sometimes to the nail.*

† *Yield a white glass or enamel.*

III.—*Mica.* Perfectly lamellar in one direction; lamellæ elastick.

†‡ *Yield a dark brownish enamel.*

VII.—*Wacke.* Greenish, greyish; amorphous; cellular.

XVIII.

Var. 1. *Argillite.* Slaty; glimmering; fragments tabular and rhomboidal.

§ *Very soft, yield to the nail.*

† *Yield a blackish slag or enamel.*

SPECIES

SUBSPECIES

XIII.—*Asbestus.* **Fibrous; flexible; unctuous.**

XVI. **I.—*Common Chlorite.*** **Blackish green; glimmering; unctuous.**

II.—*Chlorite Earth.*

XIX.

Var. 1. *Potter's Clay.* Friable, earthy fracture; strong argillaceous odour. Plastic with water; melts into a slag.

†‡ *Yield a whitish or greenish glass.*

XII.

Var. 2. *Fibrous Tremolite.* White; pearly; delicately fibrous.

XV.—*Steatite.* **Grey, green; very greasy feel; uneven and splintery fracture.**

CLASS II.—*SALINE FOSSILS.*

Sapid and soluble in water.

† *Precipitated from their solution in water by a carbonated Alkali.*

I.—*Sulphate of Iron.* **Greenish; taste astringent.**

CLASS III.—*INFLAMMABLE SUBSTANCES.*

† *Combustible with flame, leave no residum.*

I. I.—*Carburetted Hydrogen.* Gasseous.

†‡ *Combustible with flame, yield a large bulky ash, and pungent odour.*

II.

Var. 1. *Fibrous Peat.* Brownish; spongy; light.

Var. 2. *Compact Peat.* Blackish; earthy.

CLASS IV.—*METALLICK FOSSILS.*

Fixed, not volatilizable except at a white heat.

§ *Assume a metallick form after roasting on charcoal, while any thing is dissapated, and subsequent fusion with borax.*

† *Lustre metallick.*

GENUS I.

SPECIES

I.—*Pyritous Copper*. Brass yellow; semihard; decrepitates; yields a reddish brown slag.

GENUS III.

I.—*Common Sulphuret of Lead*. Lead grey, shining; soft; foliated, fragments cubical.

†‡ *Lustre non metallick.*

GENUS I.

II.—*Muriate of Copper*. Green; tinges flame bright blue and green.

§ *Not reducible to the metallick state before the blowpipe, on charcoal either with or without borax.*

†‡ *Magnetick after roasting.*

GENUS II.

I.—*Sulphuret of Iron*. Brass yellow, metallick lustre; in cubes, or amorphous; hard; vapour sulphureous.

II.—*Magnetick oxide of Iron*. Faintly glimmering; streak greyish black; magnetick with polarity.

III.—*Micaceous oxide of Iron*. Splendent; shining; streak brownish purple red; foliated.

SPECIES

IV.—*Ochrey brown oxide of Iron.*—Colour and soil brownish orange ; smell, taste, and fracture earthy ; friable.

V.—*Nodular Iron Stone.* Streak grey, yellowish, or brownish ; semihard or soft ; in rounded or oval masses.

VI.—*Carbonate of Iron.* Structure foliated ; fragments imperfectly rhomboidal ; effervesces feebly with nitric acid.

†‡ ***Not magnetick after roasting.***

GENUS IV.

I.—*Earthy oxide of Manganese.* Fuses into a black slag ; tinges borax purple.

CLASS I.—*EARTHY FOSSILS.*

ORDER I.

GENUS I.—*LIME.*

SPECIES I.—*PHOSPHATE OF LIME.*

Subspecies I.—*Apatite.*

Apatite, *Cleaveland*, p. 151. Idem, *Aiken*, p. 188. Appatite, *Jameson*, vol. I. p. 536. Phospholite. *Kirwan*, vol. I. p. 128.

External Characters.

Its colour is green, of which it occurs celandine and mountain green.

Its lustre is glimmering and vitreous.

It is translucent.

It is crystallized in hexagonal prisms. The crystals are small and short; their surface smooth, transversely rent, sometimes slightly, longitudinally striated; crystals are single and imbedded.

The streak is whitish.

It is semihard.

The cross fracture is fine grained uneven, small splintery and foliated. The cleavage is single, parallel to the bases of the prism, but it is imperfect and indistinct.

It is brittle.

It is easily frangible.

It phosphoresces when laid on a heated iron.

Chymical Characters.

It is infusible before the blowpipe; but it is soluble in nitrick or muriatick acid with very slight effervescence, and it is precipitated by ammonia.

Geological Situation and Locality.

It occurs in small quantity disseminated in Chelmsfordite and Limestone at Chelmsford.

SPECIES II.—*CARBONATE OF LIME.*

Of this mineral the following subspecies and varieties occur, viz.

Subspecies I.—*Calcareous Spar.*

Calcareous Spar, *Cleaveland*, p. 148. Calc Spar, *Jameson*, vol. I. p. 488. Common Spar, *Kirwan*, vol. I. p. 86. Carbonate of Lime, *Aikin*, p. 174.

Variety I.—Crystallized Calcareous Spar.

External Characters.

Its colours are white, and yellowish white.

Its lustre is shining and glistening, and is between vitreous and pearly.

It is translucent and sometimes slightly opaque.

It is crystallized in acute rhombi, and the crystals are small and very small, united by their edges and faces; surfaces of the crystals slightly striated.

It is semi-hard.

The fracture is straight, foliated, with a threefold cleavage parallel to the faces of the crystals.

It is brittle.

It is easily frangible.

The fragments are rhomboidal.

Its specifick gravity is about 3.322.

Chymical Character.

It is infusible before the blowpipe.

Geological Situation and Localities.

It occurs disseminated and in small veins in Argillite at Charlestown; and in Amygdaloid at Brighton.

Variety II.—Laminated Calcareous Spar.

External Characters.

Its colours are white, grey, and green. Of white, it occurs milk white and yellowish white; of grey, ash grey and greenish grey; of green, it occurs blackish green.

Its lustre alternates from splendent to shining and glistening; and is vitreous inclining to pearly.

It is translucent at the edges and in thin lamina transparent.

It is amorphous and in amygdaloid shaped pieces.

The streak is whitish.

It is semi-hard.

The fracture is perfectly straight foliated, with a threefold cleavage parallel to the sides of a rhomboidal prism; some specimens present a fine splintery fracture.

It is brittle.

It is easily frangible.

The fragments are perfectly rhomboidal.

Its specifick gravity is about 2.737.

Chymical Character.

It is infusible before the blowpipe.

Geological Situation and Localities.

It occurs massive, disseminated and in veins of various thickness, in Argillite and Greenstone, at Charlestown, Watertown, Waltham, Brighton, Danvers, and in Amygdaloid at Brighton and at the Lower falls in Newton.

Remark.

The green colour of this variety is probably produced by Epidote.

Subspecies II.—*Granular Limestone.*

Granular Limestone. *Cleaveland*, p. 151. *Jameson*, vol. I. p. 484. Foliated and Granular Limestone. *Kirwan*, vol. I. p. 84. Variety of Carbonate of Lime. *Aikin*, p. 175.

External Characters.

Its colours are white, grey and blue. Of white, it occurs bluish white, and reddish white; of grey, ash grey and bluish grey; of blue, greyish blue.

Its lustre is shining and glimmering; and is vitreous and pearly.

It is translucent at the edges.

It is amorphous.

The streak is whitish.

It is semi-hard.

The fracture is straight foliated; fine grained uneven and splintery.

It is easily frangible.

The fragments are indeterminately angular, and not particularly sharp edged.

It phosphoresces by friction, and when projected in powder on a heated iron.

Its specifick gravity is about 2.874.

Chymical Character.

It is infusible before the blowpipe.

Geological Situation and Locality.

It occurs in a bed in Micaceous Schistus at Chelmsford.

Use.

It is employed for various purposes, after being deprived of its water and carbonic acid, by burning.

Subspecies III.—*Fibrous Limestone.*

Fibrous Limestone, *Cleaveland*, p. 156. Common Fibrous Limestone, *Jameson*, vol. I. p. 497. Fibrous Carbonate of Lime, *Aikin*, p. 175.

External Characters.

Its colour is snow white.

Its lustre is faintly glistening and silky.

It is translucent at the edges.

It is amorphous.

It is very soft.

The cross fracture is fine splintery, the longitudinal fracture is fine straight fibrous.

It is easily frangible.

The fragments are splintery.

Its specifick gravity is about 1.941.

Chymical Characters.

It is infusible before the blowpipe; but totally soluble in diluted nitrick or muriatick acid with effervescence.

Geological Situation and Localities.

It occurs in thin veins in Wacke, at Milton and Needham. Rare.

Remarks.

The fossil bears great resemblance to Fibrous Gypsum, for which this has probably been taken by some mineralogists in this vicinity, or who have visited this part of our country, but its chymical characters sufficiently distinguish it from Gypsum.

Subspecies IV.—*Compact Limestone.*

Compact Limestone, *Cleaveland*, p. 157. Common Compact Limestone, *Jameson*, vol. I. p. 477. Common Limestone, *Aikin*, p. 176.

External Characters.

Its colours are white, greyish white, and yellowish white.
Its lustre is glistening and pearly.
It is translucent.
It is amorphous.
The streak is similar.
It is semi hard.
The fracture is fine grained uneven.
It is brittle.
It is easily frangible.
The fragments are undeterminately angular.

Chymical Character.

It is infusible before the blowpipe.

Geological Situation and Localities.

It occurs in Argillite, in veins of various thickness, from that of writing paper to the fourth of an inch. Sometimes very thin lamina may be procured, six or eight inches square; these often divide the Argillite into rhomboidal tables; at the slate quarries in Charlestown, also massive and disseminated in Amygdaloid at Brighton.

Subspecies V.—*Concreted Carbonates of Lime.*

Calcareous Incrustations. *Cleaveland*, p. 168.

These are without difficulty reduced to any distinct varieties.

Their colour varies from white and yellowish white to wax yellow.

They occur dendritick, ramous, in plates and in various imitative forms, investing Argillite and Greenstone. Frequently they resemble the forms assumed by drops of water or oil, when gently pressed between two plates of glass. In their other characters they resemble the preceding subspecies.

Geological Situation and Localities.

They occur incrusting Greenstone and Argillite at Charlestown and Medford.

Subspecies VI.—*Brown Spar.*

Brown Spar, *Cleaveland*, p. 175. Foliated Brown Spar, *Jameson*, vol. I. p. 511. Sidero-calcite, *Kirwan*, vol. I. p. 105.

External Characters.

Its colours are white and yellowish white. The external surface is generally tarnished of a yellowish colour, between honey yellow and buff orange.

Its lustre alternates from dull to glistening, and is pearly.

It is translucent at the edges.

It is amorphous and crystallized in straight planed rhombs and in lenses. The crystals vary in size from a pin's head to the size of an almond ; they occur variously aggregated, are generally hollow and the cavity is filled with minute rhombick crystals. Rhombick crystals appear to compose both the lenses and rhombs, and their aggregation gives the crystals a striated surface, which is frequently chatoyant, always pearly, and sometimes rough with mamillary incrustations.

The streak is white.

It is semi-hard.

The fracture is straight foliated, with a threefold cleavage, parallel to the sides of a rhomboidal prism. Some specimens present an imperfect granular structure, which arises from the aggregation of very minute rhombick crystals.

It is brittle.

It is easily frangible.

The fragments are rhomboidal.

The specifick gravity is about 2.90.

Chymical Characters.

It is infusible before the blowpipe. The colour is changed by heat to reddish brown and the mass becomes friable.

Geological Situation and Locality.

It occurs in veins and in fissures traversing Argillite, at Charlestown.

CLASS I.—ORDER II.

SPECIES I.—*QUARTZ.*

Subspecies I.—*Common Quartz.*

Common Quartz, *Cleaveland*, p. 210. *Jameson*, vol. I. p. 152. Quartz, *Kirwan*, vol. I. p. 242. *Aikin*, p. 192.

External Characters.

Its colours are white, orange, black and grey. Of white, it occurs greyish white, and yellowish white; of orange, it occurs reddish orange; of black, greyish black; and of grey, greenish grey and blackish grey.

Its lustre alternates from shining to glistening and glimmering, and is vitreous and resinous.

It is transparent, or translucent, or opaque.

It is amorphous and crystallized,

1. In six-sided prisms, acuminated at one or both extremities by six planes.

2. In simple six-sided pyramids. The edges and angles of the prisms are variously bevilled, and their sides are sometimes transversely striated, but the faces of the pyramids are smooth and highly polished. They occur single or aggregated, and sometimes embedded twin crystals are united longitudinally.

The crystals are small and very small, and in the latter case, they frequently invest other minerals, or line cavities, rendering them drusy.

It is very hard.

The fracture is from coarse to fine splintery and imperfectly flat conchoidal.

It is brittle.

It is rather difficultly frangible.

The fragments are indeterminately angular, and sharp edged.

It is phosphorescent, when two pieces are rubbed together, exhaling a peculiar odour.

Its specifick gravity is about 2.636.

Chymical Character.

It is infusible before the blowpipe without addition.

Gelogical Situation and Localities.

It occurs massive, disseminated and in veins, in Grey-wacke, Sienit, Greenstone, Argillite and Granite; also in rolled masses, in angular pieces, and in small grains, at Roxbury, Milton, Cambridge, Charlestown, &c. &c. Very fine specimens occur on the Dedham turnpike and in Brookline. It is one of the most frequent minerals in this vicinity.

Variety I.—*Limpid Quartz.*

Limpid Quartz, *Cleaveland*, p. 211. Rock or Mountain Crystal, *Jameson*, vol. I. p. 143. Mountain Crystal, *Kirwan*, vol. I. p. 241. Quartz, *Aikin*, p. 192.

External Characters.

It is colourless.

It is irised.

It is transparent.

It is amorphous.

Its surface is smooth and undulated.

It is very hard.

The fracture is conchoidal, and flat conchoidal.

It is easily frangible.

The fragments are angular and very sharp edged.

Its specifick gravity is about 2.764.

Chymical Character.

It is perfectly infusible without addition before the blowpipe.

Geological Situation and Localities.

It occurs in angular pieces, in alluvial soil at Simon's Hill, and at Lechmere Point, on the banks of Charles river, Cambridge.

Subspecies II.—*Hornstone.*

Hornstone, *Cleaveland*, p. 230. Splintery Hornstone, *Jameson*, vol. I. p. 161. Hornstone, *Aikin*, p. 199.

External Characters.

Its colour is grey, between bluish grey and greenish grey.

It is dull and waxy.

It is translucent at the edges.

It is amorphous.

It is extremely hard.

The fracture is fine splintery, passing into even, and imperfectly flat conchoidal.

It is tough.

It is difficultly frangible.

The fragments are indeterminately angular and sharp edged.

Its specifick gravity is from about 2.67 to 2.78.

Chymical Characters.

It is infusible before the blowpipe, but becomes white when long exposed to its action.

Geological Situation and Locality.

Occurs in a small vein, in Sienite at Cohasset. Rare.

SPECIES II.—*PETROSILEX.*

Petrosilex, *Cleaveland*, p. 242. Compact Feldspar, *Jameson*, vol. I. p. 276. Continuous Feldspar, *Kirwan*, vol. I. p. 323. Compact Feldspar, *Aikin*, p. 213. Chert of some mineralogists.

External Characters.

Its colours are white, red, grey, green and black. Of white, it occurs greenish white; of red, brownish red, cochineal red, and brownish purple red; of grey, yellowish grey; of green, leek green and olive green, and of black, greyish black. All the colours are of various intensity, and frequently two or more of them occur in dots, or in stripes and zones, either parallel or in undulating curves.

Its lustre is dull, and faintly glimmering.

It is translucent at the edges.

It is amorphous.

It is extremely hard passing into very hard.

The fracture is from coarse to very fine splintery; even passing into coarse grained uneven, and small passing into imperfectly large conchoidal; the structure of some specimens is slaty.

It is tough.

It is very difficultly frangible.

The fragments are indeterminately angular and sharp edged.

Its specifick gravity is from about 2.69 to 2.79.

Chymical Characters.

It is fusible without addition, before the blowpipe. Different specimens are fused with greater or less ease; generally they must be subjected to the blowpipe flame for one or two minutes, and even then, the edges and angles only become converted into a whitish frit or enamel, filled with bubbles. Some specimens yield a blackish glass.

Geological Situation and Localities.

Petrosilex is one of the most abundant minerals in the vicinity of Boston. It enters into the composition, and forms the basis of Porphyry in Malden and Lynn, and of itself, sometimes forms hills and presents high mural precipices. Elegant striped varieties are found at Milton; rolled masses and fragments are found in alluvial soil in Cambridge, West Cambridge, Medford, Newton, Roxbury, &c. and is disseminated in Amygdaloid at Hingham. It is one of the most frequent pebbles on Nahant, Nantasket, and Chelsea beaches.

Remarks.

The external surface of this mineral often appears earthy; this arises from its great tendency to decomposition. Epidote, Feldspar, Quartz and Sulphuret of iron are not unfrequently imbedded in it, but not so abundantly as to render it porphyritick; some specimens are covered with beautiful dendritick impressions of black oxide of manganese, which often gives a uniform dark colour to a large surface.

No mineral in this vicinity has so often been confounded with Jasper and Porphyry, by mineralogical students, as Petrosi-

lex; but the infusibility of Jasper, even when the blowpipe flame is urged by oxygen gas, and the compound structure of Porphyry readily distinguish these from Petrosilex.

SPECIES III.—*MICA.*

Mica, *Cleaveland*, p. 252. Idem, *Kirwan*, vol. I. p. 210. Idem, *Aikin*, p. 215. Mica or Glimmer, *Jameson*, vol. I. p. 341.

External Characters.

Its colour is grey; of which it occurs yellowish grey, and blackish grey, passing into brownish black.

Its lustre is splendent.

It is translucent at the edges, and in thin lamina transparent; the blackish varieties, when in thin lamina, transmit a blood red or yellowish light.

It is amorphous.

Its streak is greyish white.

It is flexible, elastic, and produces a snapping sound when bent.

It is very soft.

Its structure is perfectly straight foliated, with a single cleavage, and easily separable.

It is tough.

It is sectile.

Its specifick gravity is about 2.923.

Chymical Characters.

Before the blowpipe, when in thin slender pieces, it curls like horn, and then fuses into a greyish white enamel.

Geological Situation and Localities.

Mica forms a constituent part of Granite, at Carlisle, where it is found in lamina several inches square; it is disseminated also in Limestone at Chelmsford. Small quantities occur in Greenstone, at Watertown and Waltham; and in Sienite on the Newburyport turnpike. The black varieties are frequently found in Quartz, at Brighton and Charlestown. The alluvial soils borrow from Mica the beautiful spangled appearance, which they so frequently present.

SPECIES IV.—*SCHORL.*

Common Schorl, *Cleaveland*, p. 261. *Jameson*, vol. I. p. 121. Schorl, *Kirwan*, vol. I. p. 265. Common Schorl, *Aikin*, p. 233.

External Characters.

Its colour is velvet black.

Its lustre is shining and vitreous.

It is opaque.

It occurs crystallized in long, slender, triangular, prisms with convex sides, and in cylinders. The crystals are seldom well defined, and are with difficulty separated from their bed without destruction; they are long slender and frequently intersect each other, and their most usual form is a cylinder, compressed on one or more sides.

The cross fracture is fine grained uneven; the longitudinal fracture is foliated.

It is brittle.

It is easily frangible.

The fragments are splintery and indeterminately angular.

Its specifick gravity is 3.64.

Chymical Character.

Before the blowpipe it melts into a black porous slag.

Geological Situation and Localities.

It occurs disseminated in rolled masses of Granite at Cambridge, Brighton, &c. &c.

SPECIES V.—*FELDSPAR.*

Common Feldspar, *Cleaveland*, p. 266. Idem, *Kirwan*, vol. I. p. 316. Idem, *Aikin*, p. 212. Fresh Feldspar, *Jameson*, vol. I. p. 279.

External Characters.

Its colours are white, yellow, red, brown, and black. Of white, it occurs greyish white, and reddish white; of yellow, cream yellow; of brown, light red brown; of red, aurora red and flesh red; of black, velvet black.

Its lustre is shining approaching to splendent, and is vitreous; sometimes dull.

It is opaque, or slightly translucent at the edges.

It is amorphous and crystallized in tables and rhombs, whose angles are often truncated. The crystals occur single or variously aggregated; they are small and very small, and are often hollow.

It is hard.

The fracture is foliated, the cross fracture is fine grained uneven, and fine splintery.

It is brittle.

It is easily frangible.

The fragments are tabular, approaching to rhomboidal, or indeterminately angular and sharp edged.

Its specifick gravity is from about 2.60 to 2.655.

Chymical Character.

Before the blowpipe it fuses into a whitish glass or enamel.

Geological Situation and Localities.

Feldspar is a component part of the rocks in this vicinity, as Sienite, Greenstone, Porphyry, and Granite. At Carlisle, a beautiful cream coloured variety is found, which is easily frangible, and the fragments are rhomboidal. The reddish varieties are found chiefly at Burlington and Wilmington, in Granite. At Charlestown a curious variety is found in a bed of Sienite in Greenstone. The mass is a union of singular crystals, which are either parallelopipedons or tables; they have generally a white nucleus surrounded by lamina of a red or green colour, which are perfectly well defined and distinct from the nucleus, the latter sometimes disappears, and the cavity is studded either with crystals of Epidote or Quartz, or it is filled with Hornblende The blackish variety is found imbedded in Greenstone porphyry at Charlestown.

SPECIES VI.—*BASALT.*

Amorphous Basalt, *Cleaveland*, p. 280. Basalt, *Jameson*, vol. I. p. 369. Common Trap, *Aikin*, p. 236.

External Characters.

Its colour is greyish black.

Its lustre is dull, or faintly glimmering, and glimmering from the admixture of foreign particles.

It is amorphous and corroded.

It exhales a faint argillaceous odour when breathed upon.

Its streak is greyish white, and dull.

It is hard, gives a few sparks with steel.

The fracture is fine grained uneven.

It is brittle.

It is difficultly frangible.

The fragments are indeterminately angular, and not particularly sharp edged.

Its specifick gravity is about 2.823.

Chymical Character.

Before the blowpipe it melts into a shining black enamel.

Geological Situation and Locality.

It occurs in beds in Argillite at Charlestown, and in rounded masses, at Cambridge and Charlestown.

Remarks.

This basalt contains imbedded Hornblende, sometimes scales of black Mica, black Feldspar, and Iron pyrites. Some varieties approach to Wacke and some to Greenstone. The external sur-

face is frequently decomposed, leaving the crystals of Hornblende projecting and quite perfect; in consequence of this decomposition, we often find the external surface converted into a brownish earthy crust.

It is not without some hesitation, that we have pronounced this mineral Basalt,* between which and Wacke, there is so intimate an alliance that no two minerals oftener pass into each other. We have carefully compared this mineral with Basalt from the Giant's Causeway, and their external characters present no differences, the results of their fusion are the same, and this, together with its dull streak, great hardness, and difficult frangibility entitle us to call it Basalt.

SPECIES VII.—*WACKE.*

Wacke, *Cleaveland*, p. 287. Wacce, *Jameson*, vol. I. p. 376. Wacken, *Kirwan*, vol. I. p. 223. Wakke, *Aikin*, p. 254.

External Characters.

Its colours are grey and purple. Of grey, it occurs blackish grey and greenish grey; of purple, lavender purple. The colours vary much in their intensity.

It is dull.

It is amorphous and cellular.

It exhales a strong argillaceous odour when breathed upon.

It adheres to the tongue.

Its streak is greyish white, with a reddish purple tinge in some parts, and is dull.

* See Cleaveland's Mineralogy, pp. 283, 284.

It is moderately hard, passing to soft.

The fracture is from fine grained uneven to earthy; some specimens show a slightly slaty structure.

It is brittle.

It is easily frangible.

The fragments are indeterminately angular, and not particularly sharp edged.

Its specifick gravity is about 2.88

Chymical Characters.

Before the blowpipe it melts into an opaque, semi-vitreous mass, which appears porous when broken.

Geological Situation and Localities.

It occurs in beds in Petrosilex at Milton, and forms the basis of Amygdaloid at Brighton, Hingham, Newton, &c. and it is found also in rounded fragments at Needham, Newton, Brighton, &c.

Remarks.

This mineral sometimes much resembles ferruginous clay, and is intermediate between Clay and Basalt. It is very liable to decomposition, and when it forms the basis of Amygdaloid, by undergoing this change, it leaves the imbedded minerals projecting, or they fall out and leave the Wacke cellular.

SPECIES VIII.—*COMMON GARNET.*

Common Garnet, *Cleaveland*, p. 293. Idem, *Jameson*, vol. I. p. 69. Idem, *Aikin*, p. 240.

External Characters.

Its colours are red and brown. Of red, it occurs venous blood red, and brownish red; of brown, reddish brown.

Its lustre is shining and resino-vitreous.

It is slightly translucent at the edges, and some small crystals are transparent.

It occurs crystallized in,

1. A dodecaedron, the solid angles of which are frequently truncated.

2. A double eight-sided pyramid accuminated by four planes, the lateral planes of the one being set on the lateral planes of the other, and the acuminating planes set on the alternate and different edges of the pyramids; the whole presenting a figure bounded by twenty four unequal trapezoidal faces. The surface of the crystals is smooth and shinning; and sometimes slightly diagonally striated. The crystals are small and middle-sized, and all around crystallized. They are often imbedded in each other, and the double eight-sided pyramids sometimes easily separate at their bases.

Its streak is reddish white.

It is hard; some specimens scratch quartz.

The fracture is foliated; and imperfectly small conchoidal; the cross fracture is fine grained uneven.

It is brittle.

It is easily frangible.

The fragments are tabular and splintery.

Its specifick gravity is from about 4.06 to 4.20.

Chymical Character.

It is fusible before the blowpipe into a greyish black enamel.

Geological Situation and Localities.

The large crystals occur imbedded in Granite, at Bedford; the smaller, in rounded masses of Granite, at Cambridge, West-Cambridge, and Charlestown.

SPECIES IX. *EPIDOTE.*

Epidote, *Cleaveland*, p. 297. Pistazite, *Jameson*, vol. II. p. 530. Glassy-Actinolite, *Kirwan*, vol. I. p. 168. Thallite, *Aikin*, p. 277.

External Characters.

Its colour is green; of which it occurs olive green, blackish green and siskin green; all the colours are of various intensity, and the siskin green is doubtless owing to the intermixture of reddish white quartz.

Its lustre is shining and glimmering, and is vitreo-resinous and vitreous.

It is opaque; some of the crystallized varieties approach to translucent.

It occurs amorphous, and crystallized in,

1. Acicular six-sided prisms.

2. In four-sided prisms. The crystals are seldom well defined, and their forms are determined with difficulty; they are often fascicularly and promiscuously aggregated; they are small and very small; and their surfaces are longitudinally striated, and the four-sided prisms are transversely rent.

The streak is similar, and in the lighter coloured specimens, whitish.

It is hard.

The fracture is fine splintery, fine grained uneven, and flat conchoidal; promiscuous and fascicularly diverging radiated.

It is brittle.

The crystallized varieties are easily frangible; the amorphous are tough.

The fragments are splintery, indeterminately angular, and not sharp edged.

Its specifick gravity is about 8.368.

Chymical Character.

Before the blowpipe fuses into a dark green glass or enamel.

Geological Situation and Localities.

Epidote is found in most of the rocks in the vicinity of Boston; they owe their green colour chiefly to the presence of this mineral. It traverses Greenstone, Sienite and Petrosilex in veins, which are sometimes several inches thick; it is disseminated in Amygdaloid at Brighton; and it frequently lines cavities in Prehnite. The finest specimens are found at Nahant, where it also occurs in the greatest abundance.

Remarks.

No mineral has been so unfortunate in its number of names as Epidote, and it has only recently been admitted as a distinct species. It will not be always easy to recognize it by its external characters, but its habitudes before the blowpipe will readily distinguish it from Prase and Jade, with which it has frequently been confounded by mineralogists in this vicinity.

SPECIES X.—*PREHNITE.*

Massive or Fibrous Prehnite, *Cleaveland*, p. 305. Prehnite, *Jameson*, vol. I. p. 204. Massive Prehnite, *Aikin*, p. 252.

External Characters.

Its colours are white and green. Of white, it occurs greenish white; and of green, leek green, blackish green, bluish green, asparagus green and olive green.

Its lustre is glimmering and glistening; and is pearly.

It is translucent at the edges.

It is amorphous, tuberous and cellular.

The streak is greenish white.

It is hard.

The fracture is fine splintery, fine grained uneven, and fine diverging radiated.

It is brittle.

It is easily frangible.

The specifick gravity is from about 2.346 to 2.411.

Chymical Characters.

Before the blowpipe it intumesces, and melts into a yellowish frothy glass.

Geological Situation and Locality.

It occurs imbedded in Greenstone at Charlestown.

Remarks.

Cavities not unfrequently occur in this mineral studded with crystals of Quartz or Epidote. Feldspar often occurs in it, and large crystalline grains of white Prehnite are imbedded in the green.

SPECIES XI.—*SCHAALSTONE.*

Subspecies I.—*Chelmsfordite.*

External Characters.

Its colours are white, grey, green, and red. Of white, it occurs snow white, and greenish white; of grey, ash grey and bluish grey; of green, siskin green; and of red, rose red. White is the most common colour, the others occur in veins or clouds.

Its lustre is glistening and pearly, glimmering and resino-vitreous, or dull.

It is translucent at the edges; some specimens are translucent.

It is amorphous, and crystallized in prisms which are either rectangular, or slightly rhomboidal. The lateral edges are sometimes truncated, and the acute and opposite edges of the rhomboidal prism, are sometimes so deeply truncated, that an imperfect hexagonal prism is produced. The surface of the crystals is deeply longitudinally striated, and transversely rent. The crystals are variously aggregated, sometimes they are longitudinally united, but they are generally promiscuously intersecting.

The streak is greyish white.

It sometimes occurs in straight lamellar, and in prismatick imperfect distinct concretions.

It is semi-hard, passing into hard.

The fracture is splintery, fine grained uneven and imperfectly foliated. The crystals present a single cleavage parallel to the bases of the prisms, but generally the cleavage is indistinct.

It is brittle.

It is easily frangible.

The fragments are imperfectly tabular, and indeterminately angular, and sharp edged.

It phosphoresces with a brilliant green light, when projected in powder on a heated iron.

The specifick gravity is from 2.10 to 2.60.

Chymical Characters.

Before the blowpipe it fuses with ebullition into a white enamel filled with bubbles. The amorphous, when placed in nitrick acid, feebly effervesces and falls partially into grains.

Geological Situation and Locality.

It occurs massive and disseminated in a bed of Carbonate of Lime in Micaceous Schistus, at Chelmsford. Its accompanying minerals are Quartz, black Mica, and Phosphate of Lime.

Remarks.

Schaalstone we have never seen; it is a very rare mineral and has only two known localities. The above mineral bears a greater resemblance to Schaalstone, as described by systematick writers, than to any other fossil; but, there are also considerable differences. Schaalstone is said to be phosphorescent merely by the friction of steel point; the mineral above described exhibits no such property, but it is brilliantly phosphorick, when placed on a heated iron; this may be the case with Schaalstone, but it is not mentioned by any author we have seen. Its fusibility, and its very imperfect tabular structure, likewise distinguish

it from Schaalstone.* From these circumstances, we have ventured to place it as a subspecies of Schaalstone, and from its locality, have denominated it *Chelmsfordite*. It has been shown to several distinguished mineralogists in this part of our country, who were unacquainted with it, but should it ultimately prove to be Schaalstone, we shall feel ourselves more happy, in having discovered a new locality of this very rare mineral, than in adding a new subspecies.

SPECIES XII.—*TREMOLITE.*

Variety I.—*Common Tremolite.*

Common Tremolite, *Cleaveland*, p. 323. Idem, *Jameson*, vol. I. p. 466. Bladed Tremolite, *Aikin*, p. 234.

External Characters.

Its colours are white and green. Of white, it occurs greenish and greyish white; and of green, pale asparagus green, and bluish green.

Its lustre is glistening and glimmering, and is pearly.

It is translucent at the edges, passing into semi-transparent.

t s amorphous.

The streak is whitish.

It is soft, but sufficiently hard tc slightly scratch glass.

The structure is coarse parallel brous, passing to imperfectly foliated; the longitudinal fracture is splintery, and the cross fracture is uneven.

* "It is named Schaalstone, which in German intimates that it is composed of lamellar distinct concretions." *Jameson*, vol. I. p. 520.

It is brittle.

It is rather easily frangible.

The fragments are splintery, indeterminately angular and sharp edged.

The specifick gravity is about 2.970.

Chymical Characters.

Before the blowpipe it fuses into a white enamel; some specimens, owing to a large intermixture of Carbonate of Lime, vigorously effervesce in diluted acids; the Lime is soon dissolved and the Tremolite remains untouched.

Geological Situation and Locality.

It occurs massive in Carbonate of Lime, at Chelmsford.

Variety II.—Fibrous Tremolite.

Fibrous Tremolite, *Cleaveland*, p. 324. Asbestus Tremolite, *Jameson*, vol. I. p. 464. Asbestiform Tremolite, *Aikin*, p. 234.

External Characters.

Its colour is snow white.

Its lustre is glistening, and completely pearly.

It is opaque.

It is amorphous.

It yields a slight argillaceous odour when breathed upon.

It is soft, and very soft.

The structure is delicately capillary, parallel fibrous and imperfectly fascicular diverging.

It is brittle.

It is easily frangible.

The fragments are splintery.

The specifick gravity is about 3.66.

Chymical Character.

It fuses before the blowpipe into a yellowish glass.

Geological Situation and Locality.

It occurs massive and disseminated in Carbonate of Lime, at Chelmsford.

SPECIES XIII.—*COMMON ASBESTUS.*

Common Asbestus, *Cleaveland*, p. 326. Common Asbest, *Jameson*, vol. I. p. 446. Idem, *Aikin*, 247. Asbestus, *Kirwan*, vol. I. p. 159.

External Characters.

Its colour is light greenish grey.

Its lustre is glistening, and pearly.

It is opaque.

It is amorphous.

It has a very slightly unctuous feel.

It exhales an argillaceous odour when breathed upon.

It adheres slightly to the tongue.

The streak is light ash grey.

It is flexible in thin fibres.

It is soft, passing to very soft.

The cross fracture is fine splintery; the longitudinal fracture is capillary parallel fibrous.

It is moderately tough.

It is rather difficultly frangible.

The fragments are splintery.

The specifick gravity is about 2.50.

Chymical Character.

Before the blowpipe it melts into a black enamel or slag.

Geological Situation and Localities.

Occurs in small quantities in Amygdaloid, and in rounded fragments of Greenstone, at Brighton; and massive, in Quartz which traverses rolled masses of Greenstone, at Dedham, where the fibres of this mineral are sometimes an inch long; by long exposure to the weather they become disintegrated and resemble saw-dust.

SPECIES XIV.—*HORNBLENDE.*

Subspecies I.—*Common Hornblende.*

Common Hornblende, *Cleaveland*, p. 335. Idem, *Jameson*, vol. I. p. 357. Idem, *Aikin*, p. 236. Hornblende, *Kirwan*, vol. I. p. 213.

External Characters.

Its colours are grey and black. Of grey, it occurs greenish grey and blackish grey; of black, greyish black and raven black.

Its lustre is glistening and glimmering, and is pearly.

It is slightly translucent at the edges.

It is amorphous, and crystallized in long acicular prisms, which are frequently diverging and interlacing.

It exhales a slight bitter argillaceous odour when breathed upon.

The streak is light greenish grey.

It is hard.

The fracture is fine grained uneven, and from small to large imperfectly straight foliated, with a two-fold obliquely intersecting cleavage, and the fractured surface is sometimes longitudinally striated.

It is very tough.

It is very difficultly frangible.

The fragments are indeterminately angular, and rather blunt edged.

The specifick gravity is about 3.084.

Chymical Character.

Before the blowpipe it melts into a dark green or black glass.

Geological Situation and Localities.

It occurs in rounded masses, at Cambridge, Brighton, West-Cambridge, Watertown, Danvers, &c. and forms a constituent part of Greenstone, and Sienite. The long acicular crystals are partially decomposed, and are found shooting through crystals of Feldspar, in some varieties of Sienite, at Charlestown.

Subspecies II.—*Basaltick Hornblende.*

Basaltic Hornblende, *Cleaveland*, p. 336. Idem, *Jameson*, vol. I. p. 365. Idem, *Aikin*, p. 235. Basaltine, *Kirwan*, vol. II. p. 219.

External Characters.

Its colour is velvet black.

Its lustre is shining.

It is opaque.

It is crystallized in equilateral six-sided prisms; the crystals are small, and middle sized; always single and imbedded.

The streak is yellowish grey.

It is semi-hard passing to hard.

The longitudinal fracture is perfectly straight foliated, with a two-fold doubly intersecting cleavage; the cross fracture is imperfectly small conchoidal.

It is moderately brittle.

It is easily frangible.

The fragments are indeterminately angular, and sharp edged.

The specifick gravity is about 3.200.

Chymical Character.

Before the blowpipe it melts into a black glass.

Geological Situation and Localities.

It occurs imbedded in rolled masses of Basalt, at Charlestown.

Subspecies III.—*Actynolite.*

Actynolite, *Cleaveland*, p. 338. Common Actynolite, *Jameson*, vol. I. p. 458. Schorlaceous Actynolite, and Common Asbestoid, *Kirwan*, vol. I. p. 168.

External Characters.

Its colours are grey and green; of grey, it occurs greenish grey; and of green, mountain green, blackish green, and asparagus green.

Its lustre is between shining and glistening, and is between vitreous and pearly.

It is opaque, or slightly translucent at the edges.

It is amorphous, or crystallized in very compressed imperfect six-sided prisms; surface smooth, or longitudinally striated, and transversely rent; the crystals are promiscuously aggregated, and collected into diverging groups.

The streak is whitish.

The fracture is parallel, and curved fibrous, promiscuous diverging, and foliated with a two-fold longitudinal intersecting cleavage; the folia have two directions parallel to the sides of a rhomboidal prism; the fractured surface is often longitudinally striated.

It is brittle.

It is easily frangible.

The fragments are splintery, and indeterminately angular.

The specifick gravity is about 3.192.

Chymical Character.

Before the blowpipe it fuses into a greenish grey enamel.

Geological Situation and Locality.

It occurs massive and disseminated in Carbonate of Lime, at Chelmsford.

SPECIES XV.—*STEATITE.*

Common Steatite, *Cleaveland*, p. 350. Steatite, *Jameson*, vol. I. p. 418, Semi-Indurated Steatite, *Kirwan*, vol. I. p. 151. Soapstone, *Aikin*, p. 249.

External Characters.

Its colours are grey and green. Of grey, it occurs greenish grey; of green, asparagus green and blackish green.

Its lustre is faintly glimmering, and dull.

It is translucent at the edges.

It is amorphous.

It has a very unctuous feel.

It gives a slight argillaceous odour when breathed upon.

It adheres slightly to the tongue.

The streak is white.

It is soft and very soft.

The fracture is uneven and splintery.

It is brittle.

It is easily frangible.

The fragments are indeterminately angular and blunt edged.

The specifick gravity is about 2.750.

Chymical Characters.

Before the blowpipe it loses colour, and fuses into a white enamel.

Geological Situation and Locality.

It occurs massive and disseminated in Carbonate of Lime, at Chelmsford.

SPECIES XVI.—*CHLORITE.*

Subspecies I.—*Common Chlorite.*

Common Chlorite, *Cleaveland*, p. 355. Idem, *Jameson*, vol. I. p. 349. Idem, *Aikin*, p. 217.

External Characters.

Its colour is blackish green.
Its lustre is faintly glimmering.
It is opaque.
It is amorphous.
It has a slightly unctuous feel.
It exhales a faint argillaceous odour when breathed upon.
The streak is mountain green.
It is very soft.
The fracture is fine grained uneven, passing to earthy.
It is moderately tough.
It is easily frangible.
The fragments are indeterminately angular and blunt-edged.
The specifick gravity is about 2.952.

Chymical Character.

Before the blowpipe it melts into a black scoria.

Geological Situation and Localities.

It occurs in thin layers in Greenstone and Argillite, at Charlestown, and massive in Quartz, at Newton, Needham, Brighton, &c.

Subspecies II.—*Chlorite Earth.*

Earthy Chlorite, *Cleaveland*, p. 355. Chlorite Earth, *Jameson*, vol. I. p. 348. Scaly Chlorite, *Aikin*, p. 218.

External Characters.

Its colour is leek green.

Its lustre is faintly glimmering.

It is opaque.

It is amorphous.

It has an unctuous feel.

It exhales a strong argillaceous odour when breathed upon.

It has a chalky taste.

It adheres strongly to the tongue.

Its soil is mountain green.

The streak is mountain green.

It is very soft.

The fracture is earthy.

It is easily frangible.

The fragments are indeterminately angular.

Geological Situation and Localities.

It occurs massive in Quartz, at Brookline and Brighton.

SPECIES XVII.—*PINITE.*

Pinite, *Cleaveland*, p. 358. Idem, *Jameson*, vol. II. p. 552. Idem, *Aikin*, p. 206. Micarolle, *Kirwan*, vol. I. p. 212.

External Characters.

Its colour is grey, of which it occurs greenish grey and blackish grey.

Its lustre is glistening, and resinous.

It is opaque.

It is crystallized in acicular six-sided prisms. The crystals are very small and imperfect, and their forms are determined with difficulty. The surface of the crystals is smooth.

The streak is light ash grey.

It is semi-hard passing to soft.

The cross fracture is foliated, with a single cleavage, perpendicular to the axis of the prism; the longitudinal fracture is uneven.

It is brittle.

It is easily frangible.

Chymical Character.

It is infusible before the blowpipe.

Geological Situation and Locality.

It occurs in very small quantity, disseminated in Basalt, at Charlestown.

Remarks.

This is a very rare mineral in this vicinity; we have met with it but very seldom, and this in quantities barely sufficient for description.

SPECIES XVIII.—*ARGILLACEOUS SLATE.*

Variety I.—*Argillite.*

Argillite, or Common Argillaceous Slate, *Cleaveland*, p. 359. Clay slate, *Jameson*, vol. I. p. 384. Idem, *Aikin*, p. 257. Argillite, *Kirwan*, vol. I. p. 234.

External Characters.

Its colours are grey and red. Of grey, it occurs bluish grey and blackish grey; these are disposed sometimes in stripes or spots; and of red, it occurs brownish purple red. The surface is sometimes rendered beautifully pavonine, irised and chatoyant from the presence of Oxide of Iron.

Its lustre is glimmering.

It is opaque.

It is amorphous.

The streak is pearl grey.

It is moderately hard.

The fracture is fine grained uneven, passing in some specimens, into imperfectly straight foliated, and in others into earthy, and it is always slaty.

It is moderately tough.

It is easily frangible.

The fragments are tabular and splintery, and often perfectly rhomboidal.

Its specifick gravity is about 2.888.

Chymical Character.

Before the blowpipe it melts into a blackish brown enamel.

Geological Situation and Localities.

It forms hills in Charlestown, Malden, Chelsea, Watertown and Quincy; and it occurs in rolled masses, and in large beds in Greenstone, at Charlestown; in Greywacke, at Brighton and Hingham, and in Sienite, at Milton and Braintree.

Use.

It never separates into tables thin enough for roof state; but it is much employed for the sides, floorings and coverings of drains, and for many other purposes, where large flat stones are required. It is extensively quarried near Powder-house hill, in Charlestown.

Variety II.—Novaculite.

Novaculite, *Cleaveland*, p. 363. Idem, *Kirwan*, vol. I. p. 238. Whetslate, *Jameson*, vol. I. p. 331. Idem, *Aikin*, p. 258.

External Characters.

Its colours are grey and green. Of grey, it occurs bluish grey, and of green, light mountain green. The colours are of various intensity, and with sometimes a tinge of red; they often alternate with each other; or they are clouded.

It is dull or faintly glimmering.

It is translucent at the edges.

It is amorphous.

The streak is greyish white.

It is hard passing to semi-hard.

The fracture is fine splintery and large conchoidal, passing into undulating.

The specifick gravity is about 2.807.

Chymical Characters.

Before the blowpipe it fuses into a greenish or blackish grey enamel.

Geological Situation and Localities.

It occurs in beds in Argillite, into which it passes, at Charlestown, Malden, Quincy, and in rolled masses at Cambridge, Brookline, Dorchester, &c.

Use.

Some of the finer varieties may be employed for giving an edge to cutting instruments.

SPECIES XIX.—*CLAY.*

Variety I.—Potter's Clay.

Potter's Clay, *Cleaveland*, p. 371. Earthy Clay, *Aikin*, p. 255. Earthy Potter's Clay, *Jameson*, vol. I. p. 304.

External Characters.

Its colours are yellow and green. Of yellow, it occurs light honey yellow, between honey and straw yellow; and of green, it occurs pale asparagus green and greenish grey. The colours are liable to variation from admixture of various foreign substances.

It is dull.

It is opaque.

It is amorphous.

When moistened, it exhales a strong argillaceous odour.

The taste is earthy.

It adheres strongly to the tongue.

It soils.

Its streak is similar but lighter.

It is friable.

It is very soft.

The fracture is from coarse to fine earthy.

It is easily frangible.

The fragments are indeterminately angular.

Chymical Character.

Before the blowpipe it fuses into a black or dark green enamel.

Geological Situation and Localities.

Clay exists in vast quantities in the vicinity of Boston, as at Charlestown, Dorchester, Cambridge, Danvers, &c.

Use.

The purest occurs at Danvers, where it is extensively manufactured into the coarser kinds of pottery. The impurer varieties are employed for making bricks.

CLASS II.—*SALINE FOSSILS.*

Genus I.—*Iron.*

SPECIES I.—*SULPHATE OF IRON.*

Sulphate of Iron, *Cleaveland*, p. 503. Iron Vitriol, *Jameson*, vol. II. p. 32. Green Vitriol, *Aikin*, p. 262. Copperas of Artists.

External Characters.

Its colours are white and green. Of white, it occurs greenish white; and of green, pale asparagus green.

Its lustre is glimmering, and vitreous, or dull.

It is opaque.

Its taste is acid and astringent.

It has a saline consistence.

Chymical Characters.

When exposed to heat, it becomes converted into the red oxide of iron; when dissolved in water, it gives a blackish precipitate or colour with tincture of galls.

Geological Situation and Localities.

It occurs with a vein of Sulphuret of Iron, in Greenstone, at Concord; and efflorescent on Argillite and massive Sulphuret of Iron, at Charlestown.

Remarks.

It is formed by the decomposition of Sulphuret of Iron, and exists in small quantities only.

CLASS III.—*INFLAMMABLE SUBSTANCES.*

SPECIES I.—*HYDROGEN GAS.*

Subspecies I.—*Carburetted Hydrogen Gas.*

Carburetted Hydrogen Gas, *Cleaveland*, p. 386. Idem, of Chymists. Fire damp of Miners.

This gas is disengaged in abundance from wet marshes or from the bottoms of small pools, or ditches where vegetable matter is decomposing; the air bubbles, so frequently observed rising through the water, consist of this gas. By filling a bell glass, or a tumbler with water and inverting it over these bubbles, the gas may be readily obtained by stirring the mud at the bottom of the pool, with a stick. When a flame is applied to it, it takes fire and burns with pale bluish light. It is composed of carbon and hydrogen; oxygen gas and carbonic acid gas are sometimes mixed with it.

SPECIES II.—*PEAT.*

Two varieties of Peat are found in large quantities in this vicinity, viz. the Fibrous Peat and the Compact Peat.

Variety I.—Fibrous Peat.

Cleaveland, p. 416.

This variety has a brownish colour, and is composed of leaves and parts of plants in a state of partial decomposition; some specimens have a very loose texture, and the different substances are readily detached from each other; others are more firm and appear to be cemented together by some vegetable substance, in a state of more complete decomposition. This variety is very

light and spongy, and swims on the surface of water; it is found near the surface of the ground, in a stratum, from a foot to several feet in thickness, and generally covering the Compact Peat. It is not employed for fuel, but is separated from the next variety and thrown into the pits formed by the excavation of peat; here it undergoes other changes, and is gradually converted into Compact Peat.

Variety II.—Compact Peat.

Compact Peat, *Cleaveland*, p. 416.

This variety has a much darker colour than the preceding, and is nearly black; it is more dense, firm and compact, and when dry exhibits an earthy fracture; no remains of organized vegetable matter can be discovered in it, excepting a few fibrillæ, and small roots. When recently dug, it is soft and slimy, and easily cut into parallelopipedons 2 or 3 inches square and 18 or 20 inches long.

These two varieties accompany and pass insensibly into each other, the more spongy and loose being found at the surface, but becoming more firm and compact as the distance from the surface increases. Trunks of trees are found in Peat, in a horizontal position several feet below the surface, and in some instances, small beds of fine silecious sand. Peat when burning gives but little flame, and emits a pungent and peculiar odour, similar to that of burning leather; it produces a strong heat, and affords an abundance of ashes, which are employed for scouring and polishing brass, &c. When Peat is burnt in a furnace, the ashes vitrify and cake together, and if moistened in this state while hot, they emit the odour of sulphuretted hydrogen.

Large quantities of both varieties of Peat are found in Newton, Lexington, Cambridge, Danvers, &c.

CLASS IV.—*METALLICK FOSSILS.*

Genus I.—*Copper.*

SPECIES I.—*PYRITOUS COPPER.*

Pyritous Copper, *Cleaveland*, p. 452. Copper pyrites, *Jameson*, vol. II. p. 193. Copper pyrites, or Yellow Copper ore, *Kirwan*, vol. II. p. 140. Yellow Copper, *Aikin*, p. 103.

External Characters.

Its colour is brass yellow; frequently tarnished brownish purple red, and pavonine.

Its lustre is shining and metallick.

It is amorphous.

The streak is similar; its powder is blackish green and faintly glimmering.

It is semi-hard.

The fracture is fine grained uneven, passing to imperfectly flat conchoidal.

It is brittle.

It is easily frangible.

The fragments are indeterminately angular and not particularly sharp edged.

Its specifick gravity is about 4.000.

Chymical Characters.

Before the blowpipe it first slightly decrepitates, then melts, with a strong sulphureous odour into a dark reddish brown porous slag, which exhibits a slight metallick lustre when broken.

Geological Situation and Localities.

It occurs at Woburn, intimately mixed with Iron, in a vein traversing Greenstone; and in rolled masses of Quartz, at Cambridge and Medford.

Remarks.

The Woburn ore when reduced affords about 40 per cent. of metal, which is an alloy of copper and iron, and so extremely hard, as to be scarcely acted on by the file.

SPECIES II.—*MURIATE OF COPPER.*

Muriate of Copper, *Cleaveland*, p. 465. Idem, *Aikin*, p. 108. Copper sand or Muriat of Copper, *Jameson*, vol. II. p. 572.

External Characters.

Its colour is verdigrise green.
It is dull.
It occurs small tuberous and in thin plates.
It soils slightly, of a greenish colour.
The streak is bluish green.
It is very soft.

Chymical Characters.

Before the blowpipe it blackens, and communicates to the flame a tinge of blue and of green; when held in the flame of a candle, the blue and green coloured flames appear. When placed in Aqua ammoniæ, it immediately renders it blue.

Geological Situation and Localities.

It occurs investing pyritous Copper, at Woburn, and Quartz and Amygdaloid, at Brighton, and in rolled masses of Granite, in Medford.

Remarks.

A green Carbonate of Copper is said to have been found in this vicinity, and for which the above described mineral has probably been taken; the chymical characters sufficiently distinguish them. We have met with no traces of Malachite or green Carbonate of Copper.

Genus II.—*Iron.*

SPECIES I.—*SULPHURET OF IRON.*

Common Sulphuret of Iron or Pyrites, *Cleaveland*, p. 478. Common iron pyrites, *Jameson*, vol. II. p. 253. Pyrites, *Kirwan*. Common pyrites, *Aikin*, p. 112.

External Characters.

Its colours are pale brass yellow and yellowish grey, frequently tarnished reddish brown and columbine.

Its lustre is shining, glimmering, and metallick.

It is amorphous, and crystallized in cubes, which are generally perfect and single; but also frequently the edges and angles of the smaller crystals are truncated, and they are variously aggregated.

The surface of the crystals is smooth and shining.

It emits a faint sulphureous odour when rubbed.

The powder is blackish green.

It is hard.

The fracture is imperfectly small flat conchoidal; fine grained uneven passing to earthy; some rare specimens show a diverging radiated fracture, which arises from a peculiar aggregation of cubick crystals.

It is brittle.

It is easily frangible.

The fragments are angular and not particularly sharp edged.

The specifick gravity is from 4.00 to 5.00.

Chymical Characters.

Before the blowpipe it splits and becomes reddish; yielding a bluish flame, and a strong sulphureous odour; it fuses into a porous black slag. When projected in powder into burning coals, it yields the odour and flame of burning sulphur.

Geological Situation and Localities.

It occurs disseminated in Argillite, Novaculite, and Greenstone, at Charlestown, Brighton, Concord, Dedham, Milton, &c. &c. and in rolled masses of Granite, at Reading and Stoneham; and in Sulphuret of Copper, at Woburn; massive in Clay, at Charlestown.

Remarks.

It is decomposed by atmospherick exposure, and converted into Sulphate of Iron. The massive variety is very rare.

SPECIES II.—*MAGNETICK OXIDE OF IRON.*

Magnetic Oxide of Iron, *Cleaveland*, p. 482. Common Magnetic ironstone, *Jameson*, vol. II. p. 269. Idem, *Kirwan*, vol. II. p. 158. Magnetic iron ore, *Aikin*, p. 113.

External Characters.

Its colour is greyish black, sometimes tarnished yellowish brown.

Its lustre is faintly glimmering.

It is amorphous.

The streak is similar, but the powder is blackish grey.

It is hard.

The fracture is fine grained uneven; some specimens show a straight foliated structure.

It is brittle.

It is easily frangible.

The fragments are indeterminately angular, and not particularly sharp edged; sometimes the fragments are trapezoidal.

It affects the magnetick needle and possesses polarity.

Its specifick gravity is about 4.714.

Chymical Character.

Before the blowpipe it decrepitates and fuses into a black slag.

Geological Situation and Locality.

It occurs in a vein in Greenstone, at Woburn, where it is intimately connected with Sulphuret of Copper.

Remarks.

It does not appear to exist in sufficient quantity to be an object for the miner, and is too much mixed with Sulphuret of Copper to be easily smelted.

SPECIES III.—*IRON MICA.*

Micaceous Oxide of Iron, *Cleaveland*, p. 488. Iron Mica, *Jameson*, vol. II. p. 282. Idem, *Aikin*, p. 116. Micaceous Iron Ore, *Kirwan*, vol. II. p. 184.

External Characters.

Its colour is grey, of which it occurs blackish grey and steel grey.

Its lustre is glimmering, shining and often highly splendent.

It is amorphous, and in thin diverging plates, which often intersect each other and form cells.

The streak is brownish purple red.

It is semi-hard.

The fracture is straight and curved foliated, with a single cleavage ; the cross fracture is fine grained uneven.

It is brittle.

It is easily frangible.

The fragments are tabular, wedge-shaped, and rather sharp edged.

Its specifick gravity is about 4.955.

Chymical Character.

Before the blowpipe it fuses into a blackish shining enamel.

Geological Situation and Localities.

It occurs in small veins in Greywacke and in Amygdaloid, at Brighton; and in Greenstone, at Charlestown; also massive and disseminated in rolled masses of Quartz, at Brighton and Newton; and in Quartz, at Blue Hill.

SPECIES IV.—*OCHREY BROWN OXIDE OF IRON.*

Ochrey brown oxide of Iron, *Cleaveland*, p. 494. Ochrey brown Iron Stone, *Jameson*, vol. II. p. 298. Brown Iron Ochre, *Kirwan*, vol. II. p. 167. Ochrey brown Iron Ore, *Aikin*, p. 118. Yellow Ochre, *Artists*.

External Characters.

Its colour is light brownish orange.
It is dull.
It is opaque.
It is amorphous.
It exhales an earthy smell when breathed upon.
It has an earthy taste.
It adheres to the tongue.
Its soil is brownish orange.
It is friable.
It is very soft.
The fracture is earthy.

Chymical Characters.

Before the blowpipe its colour changes to a deep reddish orange, and it then fuses into a blackish grey scoria.

Geological Situation and Localities.

It occurs massive and disseminated in Quartz which traverses Greenstone, and in decomposing Greenstone, at Charlestown and Medford.

SPECIES V.—*NODULAR IRONSTONE.*

Nodular Argillaceous oxide of Iron, *Cleaveland*, p. 471. Reniform Iron Ore, or Iron Kidney, *Jameson*, vol. II. p. 329. Nodular Ironstone, *Kirwan*, vol. II. p. 178. Clay Ironstone, *Aikin*, p. 119.

External Characters.

Its colour is brown; of which it occurs yellowish brown, or umber brown, and liver brown. The colours are of various intensity in the same specimen, and are arranged in concentric stripes. The umber and liver brown colours are external, and sometimes inclose a nucleus of a gall-stone yellow, or of a yellowish grey colour; the internal are generally lighter than the external colours.

It is dull.

It is opaque.

It occurs in rounded and ovate masses, from the size of a hen's to that of an ostrich's egg.

It exhales an argillaceous odour when breathed upon.

It adheres to the tongue.

The streak is pearl grey, sienna yellow, and yellowish brown, according to the colour of the part where it is made.

It is in concentrick lamellar distinct concretions.

It is semi-hard.

It is brittle.

It is easily frangible.

The fragments are indeterminately angular and not particularly sharp edged.

Its specifick gravity is from 2.000 to 3.541.

Chymical Character.

Before the blowpipe it fuses into a black scoria, and becomes magnetick.

Geological Situation and Localities.

It occurs in alluvial soil, at Cambridge, Brighton, Charlestown, Woburn, Dorchester beach, &c.

Remarks.

Although Nodular Ironstone has many localities, it is not an abundant mineral in this vicinity; solitary specimens only are found.

SPECIES VI.—*CARBONATE OF IRON.*

Carbonate of Iron, *Cleaveland*, p. 501. Sparry Ironstone, *Jameson*, vol. II. p. 308. Sparry Iron Ore, *Kirwan*, vol. II. p. 190. Idem, *Aikin.*

External Characters.

Its colour is red; of which it occurs cochineal red and brownish red.

These colours, by long exposure to the atmosphere, are converted into blackish brown.

It is faintly glimmering and dull.

It is opaque.

It is amorphous.

It adheres slightly to the tongue.

Its soil is brownish red.

The streak is deep reddish orange.

The fracture is fine grained uneven, passing into earthy, and is straight foliated, with a threefold cleavage, parallel to the faces of a rhomboidal prism.

It is brittle.

It is easily frangible.

The fragments are imperfectly rhomboidal, and indeterminately angular and sharp-edged.

Its specifick gravity is about 3.230.

Chymical Characters.

Before the blowpipe it becomes blackish brown and magnetick; fused with borax, communicates to it a dark green colour, between blackish green and olive green. It feebly effervesces in nitrick acid.

Geological Situation and Locality.

It occurs massive in rounded fragments of Quartz, in Cambridge.

It is accompanied with the sulphuret and ochrey brown Oxide of Iron.

Remarks.

By long exposure to the weather, the fracture and fragments of this mineral, which serve to distinguish it from the compact brown Oxide of Iron, become indistinct, and rhomboidal fragments are not easily obtained.

Genus III.—*Lead.*

SPECIES I.—*COMMON SULPHURET OF LEAD.*

Common Sulphuret of Lead or Galena, *Cleaveland*, p. 511. Common Lead glance, *Jameson*, vol. II. p. 346. Common Galena, *Kirwan*, vol. II. p. 216. Galena, *Aikin*, p. 123.

External Characters.

Its colour is dark bluish grey.

Its lustre alternates from splendent to shining and glimmering, and is metallick.

It is opaque.

The streak is similar, shining and metallick.

It is soft.

The fracture is curved or straight foliated, and in the latter case it has a three-fold cleavage, parallel to the faces of a cube.

It is brittle.

It is very easily frangible.

The fragments are cubical.

Its specific gravity is about 7.440.

Chymical Characters.

Be ore the blowpipe decrepitates slightly, yields sulphureous odour and fuses into a globule.

Geological Situation and Localities.

It occurs disseminated in rolled masses of Quartz, at Medford and Brighton; it is very rare, and sometimes incloses a minute crystal of Quartz.

Genus IV.—*Manganese.*

SPECIES I.—*EARTHY OXIDE OF MANGANESE.*

Earthy Oxide of Manganese, *Cleaveland*, p. 547. Friable Black Manganese Ore or Wad, *Jameson*, vol. II. p. 461, from Dr. Reuss.

External Characters.

Its colours are brown and grey. Of brown, it occurs blackish brown; and of grey, dark blackish grey.

Its lustre is faintly glimmering and is resinous.

It occurs dendritick, and in mamillary incrustations.

It adheres to the tongue.

It soils.

The streak is dark liver brown.

It is slightly friable.

It is semi-hard.

The fracture is fine grained uneven and earthy.

It is brittle.

It is very easily frangible.

The fragments are indeterminately angular and rather blunt-edged.

Its specifick gravity is about 2.222.

Chymical Characters.

Before the blowpipe it melts into a black slag; and when fused with Borax, communicates to it a violet tinge.

Geological Situation and Localities.

It occurs in beautiful dendritick impressions on, and investing Petrosilex, in Milton; the coating is sometimes half an inch in thickness, also investing Sienite, at Lynn.

COMPOUND MINERALS OR ROCKS.

We have adopted Werner's arrangement of Rocks. The following Table, founded on this arrangement, exhibits a view of the rocks we have described.

TABLE.

CLASS I.—*PRIMITIVE ROCKS.*

I.—Granite.
- *Var.* 1. Graphick Granite.
- 2. Porphyritick Granite.

II.—Argillite.

III.—Primitive Trap.
- *Var.* 1. Common Greenstone.
- 2. Greenstone Porphyry.
- 3. Green Porphyry.

IV.—Porphyry.

V.—Sienite.
- *Var.* 1. Sienitick Porphyry.
- 2. Porphyritick Sienite.

CLASS II.—*TRANSITION ROCKS.*

VI.—Amygdaloid.
- *Var.* 1. Variolite.

VII.—Greywacke.

CLASS III.—*ALLUVIAL DEPOSIT.*

VIII.—Sand.
Pebbles.
Clay.
Peat.

I. GRANITE.

I. This is a compound granular aggregated rock, consisting of Quartz, Feldspar, and Mica. Its predominant colour is some shade of grey or red; the colour of the Quartz is white, or blackish grey; that of the Feldspar is reddish, or whitish; and that of the Mica, black and grey.

II. The size of the component parts of Granite varies from very small to large, and they are united in various proportions. The Feldspar is the most abundant and consequently gives colour to the mass; next in proportion is the Quartz, which in some specimens predominates. The Mica is sometimes in large plates; that of a black colour is in plates, three or four inches long, penetrating the Feldspar; and it is sometimes entirely excluded.

III. From the various proportions of these ingredients, the aspect of Granite is much modified, and a variety of compound produced, which are termed Granite aggregates, in which Feldspar and Quartz form bases for other minerals. Quartz and Feldspar are united to each other in various ways and proportions, but Mica is not united to either of these constituents singly.

IV. Among Granitick aggregates are found,

1. *Graphick Granite.*

This rock is composed essentially of Feldspar and Quartz, with sometimes a very small proportion of Mica. The colours of the Feldspar are flesh and vase red, and it forms a basis, in which are imbedded lamina of Quartz, of a smoke or yellowish grey colour, resembling the silver grain in vegetables. When the mass is broken, in a direction transverse to the plates of Quartz, they present lines nearly parallel and regular, and which much

resemble Arabick characters; hence the name, Graphick Granite. It is one of the most superb Granitick aggregates, and receives a beautiful polish.

2. *Porphyritick Granite.*

The basis of this variety is composed of Quartz and Mica, in which are imbedded large crystalline grains of Feldspar. The colour of the Quartz is white and bluish white; that of the Mica is black. They are united in nearly equal proportions, and their size is small, and consequently the basis has a fine grained structure. The porphyritick structure is rendered very conspicuous, by the large white grains of Feldspar, which are of a beautiful lamillary structure, and of a rectangular form. Small grains of black Mica and crystals of Sulphuret of Iron are sparsely disseminated in them.

V. The minerals, which occur in Granite, are Garnets and Schorl. The great and useful peculiarity of all our Granites is the almost total absence of Sulphuret of Iron. In consequence of the decomposition of the Feldspar, some specimens are partially cellular, and their surface covered with a whitish crust.

VI. No formation of Granite is found in this vicinity. It occurs throughout the compass to which these observations are confined, in rolled masses, and it is especially abundant at Wilmington, Carlisle, and Bedford. The Graphick Granite is found at Carlisle, associated with coarse grained reddish Granite, and the transition of these into each other is abrupt; the Porphyritick occurs at Cambridge, Newton and Needham. Neither of these varieties is common.

II. ARGILLITE.

I. The characters of Argillite have been already sufficiently detailed, page 177. It forms in Charlestown, Watertown, Chelsea and Quincy gently undulating eminences; but their height will not entitle them to the rank of hills.

II. Argillite is stratified; the strata are horizontal. It is interrupted by numerous parallel rents, which have a two-fold direction and obliquely intersect each other; hence Argillite appears to be cut into rhomboidal tables. At the upper portion of the elevations, the Argillite is often wholly composed of small regular forms. The rents sometimes pursue various directions, and divide the Argillite into forms as various; the sides of the rents are sometimes separated a few inches from each other, and the interstice is filled with a kind of breccia, formed of angular fragments of Argillite, cemented by ferruginous Clay. This aggregate forms sometimes floorings to veins of Lime.

III. Argillite is the oldest rock which is to be observed, in situ, in this vicinity. It is subordinate to Greenstone, in Charlestown, Brighton and Newton, and to Sienite in Milton and Braintree. It passes into Novaculite, which forms an extensive bed in it, at Charlestown, and into Petrosilex, at Dorchester and Milton.

IV. The hills where Argillite predominates are insulated, their bases being surrounded by an alluvion.

V. Chlorite and Greenstone occur in Argillite in small beds; Calcareous Spar and Quartz traverse it in small veins; sometimes an aggregate of Calcareous Spar and Quartz, with an Argillaceous basis, is found in small veins in Argillite; the Quartz is in small crystalline grains, and the Lime is intricately associated

with it; the mass is of a bluish grey colour and effervesces with acids; by exposure to the atmosphere the surface becomes disintegrated and earthy; it is found at Charlestown. We have observed no metals in Argillite, but the Sulphuret of Iron, which by its decomposition, frequently covers the rock with a coating of rust.

III. PRIMITIVE TRAP.

I. The word Trap is applied to those rocks, which contain Hornblende as their principal ingredient. They are divided into two sections, viz. those composed principally of Hornblende, and those composed of Hornblende and Feldspar; the latter constitutes the rock, called

GREENSTONE,

of which several varieties occur.

1. *Common Greenstone.*

II. This is a granular aggregate of Hornblende and Feldspar. The general colour is greenish, greyish, or greyish black, of various intensity; the two ingredients are often united in nearly equal proportions, though sometimes the Feldspar, but generally the Hornblende predominates.

III. The colours of the Feldspar are reddish, and greenish white; the latter is the most usual, and is produced sometimes by Epidote and sometimes by Hornblende. The fracture of the Feldspar varies from quite compact to more or less perfectly foliated, and fine splintery; its lustre is shining, glistening, dull and sometimes waxy. The colours of the Hornblende are blackish and greyish green; its fracture is even, usually foliated and with a glistening lustre.

IV. The grains of Feldspar and Hornblende vary in size from very small to coarse; hence the structure of Greenstone presents a great variety, from coarse to fine grained, and from crystalline to earthy, in which the two ingredients are with difficulty distinguished. Generally, the grains are middle sized and easily perceptible.

V. The colour of the fine grained varieties is either greyish black, or dark leek green; these break into angular fragments, with sharp edges; and have sometimes a slaty structure, which arises from the great proportion of Hornblende; and where this predominates, the variety has a greyish black colour, with an aspect and structure approaching to Gneiss.

VI. Common Sulphuret of Iron occurs in small quantities, in cubic crystals, dissemiated in Greenstone; small scales of black Mica, Quartz, Prehnite, Epidote, and Calc Spar occur in it, either massive, disseminated or in veins.

VII. Greenstone is liable to decomposition; that which contains the Mica is the most, and the firm, compact, dark leek green varieties, are the least subject to this change. At Powder-house hill, in Charlestown, in the centre of Medford, in Reading, and in Woburn, the Greenstone is most completely disintegrated, and forms a beautiful reddish brown sand, which is much employed for forming hard gravel walks. At these places, the Greenstone occurs in large globular masses, with a solid nucleus, surrounded by concentrick lamina of Greenstone, in various stages of decomposition; the lamina are of various thickness, and are often easily separated. It bears some resemblance to that variety of secondary Greenstone, called Globular Rock. Globular masses appear piled on each other, like stones in a wall, and the interstices are filled with the above mentioned reddish sand.

VIII. The external surface of Greenstone frequently presents a rusty brown colour, which arises fromthe decomposition of the imbedded Sulphuret of Iron. The Oxide of Iron is found in various states and of various colours in the same specimen; near the surface, it is yellow and pulverulent; interiorly, it is more compact, and its colour is reddish brown, and often of a bright vermillion. When, by exposure to the atmosphere, the Sulphuret of Iron is not only decomposed, but removed, the surface of the rock becomes cellular, and then much resembles some varieties of Lava; such specimens are characterized by their difficult frangibility, toughness, and by the dark green colour and crystalline structure of the Feldspar, which are very evident in the compact centre of these masses.

IX. The lava-like varieties are found principally at Charlestown in rolled masses, and appear to be the result only of long exposure to the atmosphere, for in no place does Greenstone with such peculiar Feldspar, occur in situ, in this vicinity.

X. The aspect of Greenstone is much modified by the different proportions and aggregation of its component parts; among the varieties which are thus produced, two, which have been noted by Geologists, are found, though not abundantly, in this neighbourhood, viz.

I. *Greenstone Porphyry.*

Greenstone Porphyry, *Jameson*, vol. III. p. 131. Porphyritick Greenstone, *Cleaveland*, p. 610.

In this rock, the union of Hornblende with the Feldspar is intimate, and the mass often appears homogeneous; they form a basis, which includes large crystalline grains of Feldspar, of a black or greyish black colour, with a perfectly lamellar structure,

and vitreous lustre. The colour of the basis is greyish black; it is hard, difficultly frangible, and the fragments are indeterminately angular and sharp edged. Although it resists decomposition more than common Greenstone, it is partially affected by atmospherick exposure, and becomes covered with a brownish crust. This is the superb black Porphyry of the ancients, and occurs in small beds in Argillite, and in rolled masses, at Charlestown; and in veins in Greenstone, at Marblehead.

II. *Green Porphyry.*

Cleaveland, p. 611. *Jameson*, vol. III. p. 131.

The basis of this beautiful mineral has a uniform simple appearance, and requires the aid of glasses to discover its component ingredients. Its colour is of a uniform leek green, or blackish grey; it contains imbedded crystalline grains of Feldspar, which sometimes intersect each other, and sometimes two or more proceed from a centre like radii. Some specimens resemble Serpentine and Petrosilex, and are analogous to the antique green Porphyry, so highly valued by the antiquary. It occurs in Dorchester, Brookline, and Roxbury, in rounded masses, and in small quantity in veins at Marblehead, associated with the first variety.

XI. Greenstone in this vicinity has not been observed stratified. It forms gently rising hills, which sometimes present high mural precipices. It overlays Argillite, and some of its varieties occur in large beds in it, at Charlestown. It passes into Sienite at Weston, Waltham, Stoneham, and Dedham; and it is frequently interrupted by transverse parallel rents which intersect each other obliquely; hence rhomboidal masses are formed.

The veins which traverse it are small, and not parallel to each other; they are principally Quartz and Epidote, and at West-Cambridge it is traversed by veins of Sienite. The Sulphurets of Iron and Copper, the former sometimes magnetick, are the only metals which have been discovered in it. The Sulphuret of Iron occurs in a bed at Concord.

IV. PORPHYRY.

I. This is a compound rock, having a compact basis, in which are imbedded crystals or grains of other minerals, of cotemporaneous formation.

II. There are varieties of Porphyry, and they derive their names from the nature of their bases; the basis which predominates in this vicinity is Petrosilex, and consequently, the Porphyry is the Petrosileceous Porphyry; the imbedded minerals which form the other constituent parts, are Quartz and Feldspar. The colour of the basis is generally of some shade of red, between chocolate and brownish purple red, but it also occurs bluish black and greenish grey; the colour of the Feldspar is white, often with a tinge of green, grey or black, and its lustre is shining and pearly; frequently approaching to vitreous, or it is dull. Similar colours are presented by the Quartz; it is dull, and often has a greasy aspect; and it has a delicate splintery fracture, very similar to that of some varieties of Petrosilex.

III. The imbedded minerals are in nearly equal proportion; the Feldspar predominates in some specimens, and the Quartz in others. The grains of Feldspar and Quartz vary from small to middle sized, and in the black varieties they are very minute; the Feldspar is generally in rectangular crystalline grains, and the Quartz in small rounded nodules.

IV. Epidote is disseminated in this rock, though it occurs much less frequently than in any other in this vicinity, Argillite excepted. The only metal which we have observed in it is Sulphuret of Iron; this is in small quantity only, and is principally confined to the varieties which have a black coloured basis.

V. Porphyry is unstratified in this vicinity, and is intimately connected with Sienite and Petrosilex, into both of which it passes.

VI. The reddish variety is the most abundant, and is found principally in Malden, Lynn and Chelsea, where it forms hills. The blackish varieties are found in rolled masses at Chelsea, Nahant and Hingham; it approaches the Clinkstone Porphyry, and may probably be one of its varieties, for it gives a metallick sound when struck with a hammer, and separates into tables. Its structure is sometimes slightly slaty, and its fracture conchoidal and small splintery.

VII. Porphyry is sufficiently hard to give fire with steel, and is susceptible of a beautiful polish; when exposed to the action of the atmosphere the Feldspar generally first decomposes, and afterwards the basis; hence we frequently find the surface covered with an earthy crust.

V. SIENITE.

I. This rock is composed of Feldspar, Hornblende and Quartz. It is usually defined, an aggregate of Feldspar and Hornblende, sometimes admitting into its composition Quartz and Mica, but as the greatest proportion of Sienite in this vicinity contains Quartz, we have given it a place in our definition.

II. The ingredients are granular aggregated; the Feldspar predominates; and the general colour of the mass is some shade

of grey or reddish white, which, by long exposure to the atmosphere, becomes brownish.

III. The Feldspar presents several colours; generally it is reddish, sometimes cochineal red; frequently whitish, and often with a tinge of green; the latter colour is produced probably in some cases by Epidote, and in others by Hornblende; these several colours often occur in the same specimen. The lustre of the Feldspar is glistening, approaching to shining, pearly, and sometimes it has a greasy aspect; its structure is more or less perfectly foliated. The Quartz has usually some shade of white, or of blackish grey; it is also often colourless and transparent, with a perfectly vitreous lustre. The predominant colour of the Hornblende is greenish black; it is however often bluish grey, and sometimes velvet black and broccoli brown; its structure is foliated and granular, and its lustre is glistening or dull.

IV. The proportions of the various ingredients are no less various than their colours; generally the Feldspar predominates; next in quantity is the Quartz, and lastly the Hornblende; in that variety, where there is a reddish Feldspar, the Hornblende is often entirely excluded, the Quartz present in a small quantity only, and the whole mass is constituted principally of Feldspar.

V. The structure of Sienite varies from very fine to coarse granular; in the latter case, the Feldspar and Quartz are in nearly equal proportions, and sometimes the three constituents are equally abundant; in the finer varieties, the Hornblende principally predominates, and the mass appears almost homogeneous.

VI. The above description applies to the Sienite, found principally on the north and south of Boston; it forms the great range

of the Blue hills, the highest land in this vicinity; and it predominates in part of Lynn, Lynnfield, Danvers, Malden, and Chelsea; at these last places, it is associated with the second Porphyry formation.

VII. In Sienite, many varieties are produced by the proportion and aggregation of the constituent parts, and these varieties have been raised to the rank of species, by some nomenclators. Two only are now admitted by modern geologists.

1. *Sienitick Porphyry.*

The structure of this is very fine granular, and the Feldspar and Hornblende are with difficulty distinguished; it contains large grains of Feldspar and Quartz.

2. *Porphyritick Sienite.*

This has a fine granular porphyritick structure, or it is a fine granular Sienite, containing imbedded large grains of Feldspar. Both varieties occur in the range of the Blue hills; the first is in the greatest abundance; the second is also found in Malden, Chelsea, Lynn, &c. Sienite has not been observed stratified in this vicinity.

VIII. The foreign minerals, which are imbedded in Sienite, are Quartz, Mica, Epidote, rarely Garnets, and Magnetick Iron Ore. From the presence of the latter, Sienite frequently affects the magnet; the Mica sometimes forms a large proportion of the mass; and hills of Sienite, of a fine structure, containing Mica in quantity nearly equal to the other ingredients, prevail for a great extent, particularly at Danvers; Epidote and Quartz traverse it in small veins, though not in such quantities as in Greenstone. Sienite is liable to decomposition, but is less susceptible of the

change than Greenstone. It occasionally becomes so much disintegrated as to form gravel and sand; this occurs at Danvers and Lynn.

IX. Greenstone and Sienite are composed essentially of the same ingredients, viz. Hornblende and Feldspar, and much difficulty frequently attends their discrimination. The general colour of the rocks, and the particular colour of some of their component parts have been employed to assist us in distinguishing them; the Feldspar in Sienite, it is said, generally has some shade of red, while Greenstone, has generally some shade of green, not only in the Feldspar but in the whole mass; this rarely sccurs in Sienite; Greenstone seldom contains any considerable proportion of Quartz; but in the Sienite of this vicinity, Quartz forms a constituent part; this circumstance, connected with the general reddish white colour of the rock, will sufficiently distinguish them.

X. Sienite is one of the most valuable rocks in this part of the country; it splits with ease into large blocks and tables. Vast quantities are annually brought from Braintree and Weymouth, to Boston, for the purposes of building. The Stone Chapel in Boston, the State Prison, and the Prison at Lechmere Point, are built of Sienite. At Danvers, it is wrought into mill-stones, and many parts of the Union are supplied with them from this place.

VI. AMYGDALOID.

I. Amygdaloid is ranked with transition traps. It is a rock, having a homogeneous basis, which does not appear to be cotemporaneous with its imbedded simple minerals; hence it has been supposed, that the basis was cellular, and that the cells have been subsequently filled, the form of the imbedded minerals is ovate or

almond-shaped hence the name of this rock from the Latin, Amygdala. The basis is Wacke, which in some specimens very much resembles some varieties of Greenstone.

II. The imbedded minerals are Petrosilex, Quartz, Feldspar, Epidote and Carbonate of Lime. The predominant colour of the basis is brownish purple red, but when it approaches to Greenstone, it verges to greenish grey. The Quartz is the most abundant of its imbedded minerals, next is the Carbonate of Lime, next Epidote, while Feldspar and Petrosilex exist only in small quantity. These minerals present their usual characters, but the aspect of the rock is very much modified by their size, which varies from that of a pin's head to that of a pea; those of similar magnitude are generally grouped together, and frequently the transition from the minute to the larger grains is very abrupt.

III. Not only are simple minerals imbedded in Wacke, but these minerals themselves frequently inclose each other. The nodules of Quartz are sometimes hollow, and the cavity is studded with minute crystals of Epidote, and sometimes the latter encircles Quartz, with a beautiful green belt. The nodules of Lime are sometimes perfectly foliated, and nearly transparent at their centre, while their circumference is fine granular and opaque. The Epidote in the variety which resembles Greenstone often contains small crystals of Sulphuret of Iron; Hornblende is sometimes, but very rarely, found in this Amygdaloid, and there are some traces of Talc and of Muriate of Copper. Quartz traverses it in veins, and it is in them that the Iron Mica is principally found.

IV. Like the other rocks which have been described, it appears to be destitute of stratification, but it sometimes presents an im-

perfeet slaty structure. It reposes on Greywacke at Brighton, and is associated with it at Brookline, Newton and Needham.

V. A bed of very beautiful Amygdaloid is found in Greywacke, at Hingham; its basis is Wacke of a chocolate red colour, inclosing nodules of Petrosilex; the colour of the nodules is brownish red, and leek and olive green; they are from the size of a peato that of an alm ond; their fracture is fine splintery and conchoidal; sometimes the Petrosilex appears in small veins. Some of the green nodules inclose Carbonate of Lime of a laminated structure; and they are sometimes incircled with red coloured Petrosilex; and some are variegated with colours disposed veins.

Variolite

is a variety of Amygdaloid, produced by the decomposition of the basis, and the nodules project from the mass; from the fancied resemblance to the small-pox pustule, the name Variolite* has been given to it; sometimes the nodules fall out, or are decomposed, and the mass is then cellular, and appears like lava. It is found at Hingham, and in small quantities at Brighton.

VII. GREYWACKE.

I. This Rock, which geolists consider as the most important in the transition class, is certainly the most interesting in this vicinity. It is composed of nodules of Petrosilex, Quartz, Argillite, Feldspar, Porphyry and Sienite; some of these nodules approach, in magnitude, to rolled masses, and from these we find a gradual gradation to grains of sand.

* Variola, small-pox.

II. Quartz and Petrosilex are the most abundant ingredients; the former presents various colours; it is sometimes translucent, and the smaller grains are transparent; but generally it is opaque, with a splintery and imperfectly granular, or compact fracture. All the colours mentioned in the mineralogical part of this work, as belonging to Petrosilex, occur in the nodules, which are found in Greywacke, and often, some of the most beautiful varieties are contained in this rock. From its great liability to decomposition, Petrosilex is generally one of the first portions of Greywacke, which begins to decay; and it is sometimes so much altered, as to resemble indurated clay. The Porphyry has a base of reddish Petrosilex, including small crystalline grains of Feldspar, and sometimes of Quartz, but it forms a small portion only of the ingredients of Greywacke. The Argillite will be immediately recognised by its bluish slate colour, and structure. The Sienite contains transparent grains of Quartz, a small proportion of Hornblende, with crystalline grains of Feldspar, whose colour is either red or grey, with a foliated fracture and a waxy lustre. It rarely contains Epidote.

III. The nodules are not cemented by a basis of Argillite, as is frequently the case in Greywacke, but they are united by a finer grained Greywacke. The interstices between the large nodules are filled with very fine Greywacke, which sometimes appears almost homogeneous, from the very minute grains of which it is composed.

IV. Greywacke is traversed by small grains of Quartz; and Greenstone and Argillite form extensive beds in it, at Brookline, Brighton, and Newton. Amygdaloid is intimately connected

with, and forms beds in it, at Brookline, Brighton, Newton and Needham; and it sometimes passes into Wacke so abruptly, that the line of demarkation is perfectly distinct.

V. The external surface of Greywacke is always very much altered; those ingredients of it, which are most easily decomposed by atmospherick exposure are gradually removed; the Quartz frequently remains projecting from the mass, and by the farther removal of the cementing substance, this falls out; and hence the Greywacke sometimes presents smooth rounded depressions or cells once occupied by these nodules.

VI. Greywacke is generally one of the most metalliferous rocks, but except some slight traces of Iron, and dendritick impressions of Oxide of Manganese, no metals have been observed in the Greywacke above described.

VII. No stratification has been observed in this Greywacke; it is intersected by many perpendicular and parallel seams which run S. W. and N. E. and are distant from each other from 3 to 10 feet. Where the rock is intersected by these seams, its faces are perfectly smooth and the corresponding portions of the nodules are found on each side, or sometimes the nodule is entirely on one side projecting from the mass, whilst a corresponding cavity is found in the opposite portion; sometimes the faces found by this seam are a little separated from each other, and the interstice is filled with a table of Greywacke, whose component parts are much smaller than those in the two contiguous portions; these tables may be easily removed from their situation, without fracture of the rock. In some instances, we find the interstice filled by two or more of these thin tables; the perpendicular seams are frequently intersected by others, which are horizontal; hence the rock falls into

vast masses, with perfectly smooth faces. Greywacke forms hills which are rounded and of very gentle ascent.

VIII. ALLUVIAL DEPOSIT.

I. This consists of sand, pebbles, clay, and peat, and forms three varieties of soil, the sandy, marshy, and clayey. The sand is generally fine siliceous, frequently unmixed, but often united with pebbles of Granite, Quartz, Feldspar, Argillite, Sienite and Greenstone. The sand varies from very fine grained, yellowish white, to coarse, which is frequently tinged, for the extent of several feet in length, and three or four inches in thickness, with Oxide of Iron; partial deposits are frequently insulated between primitive hills.

II. The Peat occurs in immense beds at Cambridge, Lexington, Newton and Danvers. Trunks of trees, generally of some of the species of pine, are frequently found in a horizontal position in Peat, several feet below the surface, and in the marshes of Charles river.

III. Clay is abundant in this vicinity, particularly at Charlestown, Cambridge and Danvers, and like sand, it sometimes forms gentle eminences; it is subordinate to the Peat and Sand and forms the floor on which these repose. This floor of Clay is very much indurated, and in many places is almost as hard as Argillite, to which it sometimes approaches. The edges of the tools of the well-digger are with difficulty kept sharp, when breaking through this stratum; and sometimes, the drill and the spade are abandoned, and the augers used to bore through it. When this is accomplished, the well is soon filled, the water enters with great rapidity, and sometimes the tools are lost, and the lives of

the workmen are endangered. It is necessary to descend from 70 to 120 feet to penetrate through this Clay; under this, appears to be, in some places, fine sand. These facts we learn from the wells, which have been dug in several places. The pebbles and sand, or sand and clay, are not unfrequently disposed aternately in strata, which are from five inches to several feet in thickness. Often in these strata are found smooth rounded stones like those which occur on sea beaches; these stones are found at a great depth, and with the fine sand which they accompany, are often an indication to the well-digger that water is not far distant.

IV. The only organick remains, which have been observed in the alluvial deposit, are the trees above mentioned, and marine shells, which occur in Cambridge. A stratum of clam-shells (*mya arenaria*) was exposed a few years since by a violent rain; it was on the side of a hill, distant about $\frac{1}{2}$ mile from the river. Its extent was several feet and its thickness three or four inches. Some of the shells were quite perfect, but generally much comminuted. At Lechmere Point also deposits of shells have been found from five to ten feet below the surface; these strata are several inches in thickness and several feet in extent. A stratum of clam-shells and muscle-shells (*mya etmytilus*) is sometimes separated by a stratum of black loam, six or eight inches thick, from a stratum consisting chiefly of oyster-shells (*ostrea edulis*); shells of the same species are now found in the river; but others occur, which are not found nearer than Chelsea and the waters in the harbour of Boston. Fragments of the *mya arenaria* have been found forty feet below the surface at Jamaica Plains, and Loammi Baldwin Esq. shewed us the fragment of a clam-shell found at the depth of 107 feet, in digging the well at Fort Strong.

V. Large rolled fragments of Granite, Quartz, Greenstone, Greywacke, and Argillite occur in and upon this alluvion; and it is variegated with large ponds of fresh water. Charles river holds the principal part of its course, in the compass of the present observations, through alluvial soil; the banks of all the rivers are alluvial, and though rocky masses sometimes break through it, they never form the channel, through which the waters run, for any considerable extent.

VI. There does not appear to be much variation in the constituents of the well-water in this vicinity. The water from the well on Long Wharf gives indications of Muriate of Soda, and Sulphate of Lime; that from the well on Beacon Hill, near the State House, affords the same indications, as do the waters from several other wells which we have examined. Several springs containing small portions of Carbonate of Iron, are found in this neighbourhood, particularly at Brighton, Watertown, and Danvers, and one in Hingham near Nantasket Beach, within 100 feet of the waters of the Atlantic.

DESCRIPTION OF THE MAP.

From the preceding description, we perceive how few and simple are the rocks in this vicinity. Greenstone, Sienite and Greywacke form the boldest features in the structure of the country. The comparatively even surface of the district, to which these observations are confined, forms an important trait in its character; it may well be called a plain, with the exception of the Blue hills; and even these can scarcely be ranked as hills by the Geologist. The eminences, which are grouped or isolated in this vicinity, can be considered as the undulations only of a plain; they have generally a gradual and easy ascent from the north, while on the south sides they are abrupt and precipitous. At present, we see the external weathered surface only of the masses; nothing has yet tempted enterprize to open the bosoms of our hills, and lay bare to view their structure; few have been explored, and into these we have penetrated a few yards only.

If it is unphilosophical to form plans and sections of the structure of countries, where the miner has descended hundreds of feet, it is certainly absurd, to draw a diagram of that, where a single rock has not yet been penetrated to its basis. A section of the district, comprehended in this map, might indeed be made by the aid of hypothesis and imagination, and by it might be shown the connexion of the rocks from the Blue hill range on the south, to the Greenstone, on the north of Boston; by it might be shown, how the Petrosilex passes from Milton and its neighbourhood, under the Greywacke, and again appears in Malden, Lynn, &c.; it might be shown, how the transition strip reposes on the primitive rocks; and by it might be shown, a great many

other things equally as probable; but this is unphilosophical, and tends rather to support preconceived opinions, than to lead us to a correct knowledge of the structure of the globe.

Without bending to any particular theory, we cannot forbear remarking, how many proofs of the accuracy of the observations of Werner are offered by the structure of the rocks in this vicinity. These coincidences, at least, encourage the student to pursue his investigations, and invite him onward with assurances, that Geology is not the science of conjecture. The description given by the pupils of the Wernerian School, of rocks in other countries, applies nearly to similar rocks in our own; we find, so far as we have yet penetrated, that the rocks, as Sienite and Greenstone, which Werner calls newer than Argillite, repose on it, and beds of it occur in them, as noticed in other countries.

In our map, every bed or insolated alluvion is not represented; thus, alluvial hills appear from Needham to the Lower falls in Newton, pursuing the course of Charles river; yet, the Greywacke is found among them, and as they do not interrupt that formation, we have thought it not necessary to represent them. Our object has been to present to the student a view of the general disposition of the rocks, as they appear at the surface; we have gone as far as facts would guide us, and we have terminated where conjecture began.

Of the Alluvion.

(Coloured on the map, gamboge yellow.)

The principal alluvion, though irregular, may be considered as having a triangular form. Its southwest boundary is Greywacke; its southeast are the waters in the harbour of Boston, and its northwest is Greenstone principally, and Porphyry. It forms

the peninsula which connects Nahant with the main, and proceeding to the Porphyry formation in Lynn, it runs at its foot, southwesterly to Malden, and thence westerly, bounded by Petrosilex, to Medford near the banks of Mystic river; here it turns northerly, and running in between Greenstone, it meets in Wilmington and Reading, the great alluvion, which comes in through Chelmsford &c. from New Hampshire; thence, having a southwest course generally, through part of West-Cambridge and Waltham; it meets the Greywacke in Newton, and bounded by this formation, it runs southeast, through part of Brighton, Brookline, and Roxbury to Dorchester, where it meets the ocean, and the southeast boundary is the coast, from this place to Nahant.

This deposition is interrupted in three places. At Malden and Charlestown by Argillite; and at Watertown by Argillite and fine-grained Greywacke, which occurs here in small quantity; these formations appear to be insulated in the alluvion. In the peninsulas of Boston and Charlestown, and in some parts of Dorchester and Chelsea, are found the highest elevations of this deposition, as for example, Bunker's and Breed's hill, Dorchester heights, &c. and again, immense plains are formed by it, as at Cambridge and Waltham. Its greatest breadth is from four to five miles, and its narrowest portion a few rods only. At Sweet Auburn, in Cambridge, this deposition appears to have suffered some changes; it is here formed into extensive ridges, of singular regularity, and which are separated from each other by deep ravines; they bear great resemblance to ancient fortifications. In other parts, deep basons are shown, which contain small pools of water,

and if conjecture may be allowed, it is probable, that the ravines were once outlets from these basons.*

A small alluvion is found about the banks of Charles river, in Dedham and Needham, bounded by Petrosilex on the west, by Sienite on the east, and north by Greywacke; this probably reposes on Sienite and Petrosilex, which are on each side of it.

Another alluvial deposit, of considerable extent, is found stretching southeast from the Greywacke in Dorchester, through part of Quincy and Weymouth to Hingham. Its northeast boundary is the waters of Boston harbour, and its southwest is Sienite. Argillite appears in it at Quincy.

An alluvion begins in Lynn, and runs northerly through Danvers, between Sienite and Greenstone, beyond the compass of these observations.

* Mr. Eaton, in his Index to the Geology of the Northern States, published in 1818, says, that near Boston, he found fragments of Argillite, "which, with other observations, induce a belief, that it may exist under the deep alluvial deposits," p. 29. We are happy to find an opinion, which we have long entertained, confirmed by others, with whom we have no acquaintance. "The whole of this deposit, undoubtedly reposes an Argillite, which makes its appearance in the bed of Charles river, in some places. It is found on the northern and southern sides of this deposit, and as we know, that Argillite sometimes passes into Greywacke slate, may we not conclude, that it passes under this alluvion, through the bed of the river, to the Greywacke formation, and thus forms the connecting link between the rocks on the north and south sides of the Charles?" Extract from a dessertation on the Mineralogy and Geology of Cambridge, by S. L. Dana, read before the Linnæan Society of New England, March 29, 1817. The above conjecture is confined to that portion of the deposit, in the immediate vicinity of Cambridge.

Greenstone.

(Coloured on the map, green.)

This is bounded by an alluvion and Sienite, north; east, by Porphyry; by the Cambridge alluvion, south, and extends northerly and westerly beyond the compass of these observations. From the Petrosilex, in Malden and Lynn, it runs westerly, and spreads through Medford, Stoneham and Reading, to the alluvial strip, which connects the alluvion at Cambridge, and with that at Wilmington; on the west side of this strip, it includes the town of Woburn, Lexington, Lincoln, Weston and part of West-Cambridge and Waltham. In this extent, are several ponds of fresh water, of considerable magnitude.

A Greenstone formation prevails from Lynn to Marblehead, and Salem. It is separated from Sienite, on the west, by an alluvial deposit; it is intimately associated with Sienite, and no better line of demarkation between them, than this alluvial strip, is presented.

Greywacke.

(Coloured on the map, grey.)

This is an oblong strip, about two miles wide and eight or ten long. Its direction is southeast and northwest. The southeastern extremity is bounded by the waters in Boston harbour and by an alluvion in Dorchester. In Milton, it forms the falls of Neponset river, in the centre of the town, thence passing through Dorchester, Roxbury, Brookline, Brighton and Newton to Needham, where it is bounded on the southwest, by an alluvion and Petrosilex. It forms Squantum, part of Hingham, and appears again at Nantasket beach. In Hingham it is bounded by Sienite, by Petrosilex and the ocean. Its borders in many places pass into

Amygdaloid.

(Coloured Vermillion red.)

This forms the rocks at the Lower Falls, Newton, and again appears in Brighton and at Needham; whenever it is found, it occurs at the borders of the Greywacke formation. It is found also in Hingham, associated with Greywacke.

Petrosilex.

(Coloured blue.)

A narrow strip, running south-east and north-west, from Quincy to the western part of Roxbury; its extremities disappear under alluvial soil; its northern edge is bounded by Greywacke, and its southern is associated with Sienite, into which it sometimes passes. It again appears in Needham, where it forms a high pyramidal rock, called High Rock; at this place the Petrosilex is almost porphyritick; is of a greyish colour, having small hyaline grains of Quartz disseminated in it.

Another formation of Petrosilex begins at Medford, and runs nearly east and west; its south border meets the alluvion, and its north passes into Porphyry; in Malden and Lynn, it frequently appears among the Porphyry. Nahant rocks are formed of Petrosilex; and it appears also contiguous to Greywacke, near Nantasket beach in Hingham.

Argillite.

(Coloured black.)

This forms insulated hills in Watertown and Charlestown. A part of Prospect Hill and the whole of Winter Hill are formed by Argillite; it extends from Charlestown neck, north-westerly, and it disappears under alluvial soil. Argillite again appears between the Alluvion and Sienite, in Quincy, and Petrosilex and

Greywacke at Neponset Falls; it is found at Angier's Corner in Newton, and a strip enters from Malden, easterly into Chelsea and is lost under the alluvial soil.

Sienite.

(Coloured light red.)

The greatest portions of Sienite are on the south and south-east of Boston. It appears in the harbour of Cohasset, thence passing westerly, through Hingham, Weymouth, Braintree and part of Quincy, it at length forms the Blue Hills, gradually rising as it proceeds west, till it forms the highest and most western part of this range, near Canton. The direction of this group of rounded hills is nearly east and west. From the Blue Hills, the Sienite extends north-west, till it meets Greenstone in Dedham, and it terminates near the banks of Charles river. Its northern edge meets and passes into Petrosilex, at Milton, Dorchester, and Roxbury. It again appears in Needham, and thence stretches northerly to Weston and the upper part of Waltham, where it passes into Greenstone; the eastern part of this last mentioned portion is bounded by Greywacke. An extensive formation of Sienite is found on the north of Boston, bounded on the south-west by Greenstone and Porphyry, and on the east by an Alluvion; this extends through Danvers to Beverly, and thence forms the coast to Cape Ann.

Porphyry.

(Coloured orange.)

This formation extends from Malden to Lynn, and has a direction south-west and north-east; its north-western boundary is Greenstone, and its north-eastern is Sienite, into which it passes; its south-western border meets Petrosilex and its south-eastern

is bounded by the alluvion. Sienite and Greenstone sometimes appear in this range, and these rocks are very intimately associated. Porphyry and Petrosilex are so intimately combined in many places, that it is difficult to say, which ought to be represented. We have taken for the line of separation the brook which runs through Malden, and have represented the Porphyry on the north-east, and the Petrosilex on the north-west. It must be recollected, that accurate boundaries cannot easily be given to mineral formations.

XVI.

On the Pronunciation of the Greek Language.

By JOHN PICKERING, A. A. S.

The arrival of a Greek ship, called *The Jerusalem,* at Boston in the year 1814, afforded me an opportunity, which I had long desired, of making some inquiries respecting the language of the *Modern Greeks,* and of comparing it in some particulars with the unrivalled idiom of their ancestors;—a people, whose authors are still our models in writing, as their architects and sculptors are in the arts. In the course of my inquiries, many things presented themselves to notice, which highly excited my own curiosity, as well as that of some of my friends, and gave a new interest to the recollections arising from the study of the *ancient Greek* authors in our youth; and, as opportunities of conversing with Modern Greeks are extremely rare in our country, (this being the only instance of the arrival of a Greek ship in this part of America,) I have thought it would not be uninteresting to the members of the Academy to be possessed of such of the observations I made, as seemed to be most worthy of attention.

I ought here to state, that my information respecting the Modern Greek language and my instruction in the pronunciation of it, are chiefly derived from the supercargo of the ship, Mr. *Nicholas Ciclitira* (or, as he writes it in his native dialect, Νικόλαος τζικλι-

τήρας*) who has lately visited this country again, and now resides in Boston. He is a native of *Navarinos* (anciently *Pylus*) on the western coast of the Peloponnesus, and is an intelligent, well-informed man; but he has told me with much frankness and modesty, and at the same time with regret, that he had not enjoyed the advantages of a learned education; and that the education he had received (which was the common one of his country) had been of the less service to him, as he had been engaged in mercantile business all his life, and had thus been compelled to withdraw his attention from literary pursuits. He had, however, in his youth studied *Homer* and some other ancient authors, as is common in Greece at this day; but, from the circumstances above mentioned, he had in a great measure lost the knowledge which he had acquired of ancient Greek at school, and retained but little more of it than had been preserved by the daily use of his native language, the *Modern* Greek. In addition to the information thus derived, I had also frequent conversations with the master of the ship, Captain *Lazarus Nicholas Katára*, (λάζαρος νικόλας κατάρα, as he used to write it himself, who likewise spoke *Italian*,) and I frequently heard him read, particularly in the *Greek Testament*, which he appeared, in general, to comprehend without difficulty. He was a native of *Hydra*, (the ancient *Aristera*,) an island on the southeasterly side of the Peloponnesus, and celebrated for its seamen and nautical enterprize. He

* In writing his name in *Roman* letters, *Ciclitira*, he gives the letters the powers which they have in *Italian* (*Cheekleteerah*) which he speaks fluently, as is common throughout the Levant; but in *English* we might write it, in strict conformity with the Greek orthography, *Tzikliteera*. only pronouncing the *i* as in our word *magazine*. Every reader will recollect a similar combination of *Tz* in the name of John *Tzetzes*.

had been a seaman from the age of nine years; and, as he informed me, had never been at school since that early age; the effects of which deficiency in education were apparent in his reading and writing. This circumstance however (as has been justly observed in a similar case by an intelligent writer on this subject*) obviously gave his testimony the greater weight in relation to the *common language* of his country; because, as he could not be aware of the controversies among the learned in Europe on the subject of the *ancient* and *modern Greek*, it was not in his power to frame his answers to my questions in such a manner as to suit any particular hypothesis of European scholars.

I may here remark, that I have felt the greater desire to communicate to the Academy the information thus obtained respecting the *pronunciation* of the *Modern Greeks*, because it led to a strong conviction in my own mind very different from the opinion I once entertained of it. Adopting the opinion, which was first propagated with success by *Erasmus*, (who, however, did not adhere to it himself in practice,) I had long supposed their present pronunciation to be grossly corrupt, and wholly different from that of their ancestors. But the attention I have given to the subject, in consequence of my frequent conversations with the two Greeks I have mentioned, and an examination of the controversy, which took place in the age of Erasmus, (which will be more particularly noticed hereafter,) have occasioned a change in my opinion. It now appears to me highly probable, nay almost certain, that the Greeks of the present day pronounce very nearly as their ancestors did, as early as the commencement of the Christian era,

* Observations upon the Greek Accents, by Arthur Brown, Esq. published in the *Transactions of the Royal Irish Academy*, vol. vii. p. 359.

or at least just after that period. As this opinion, however, is contrary to that which has prevailed among our countrymen, and probably among most members of the society I am now addressing, I have thought it proper to exhibit, as concisely as possible, some of the principal arguments upon which it is founded. In doing this, I shall make no pretensions to new or original remarks; but shall only attempt to select such facts and observations of the writers on this subject, as appear to be the most important in a general view of the question; and such as may, I hope, incite some persons of more leisure and ability than myself, to prosecute this interesting inquiry.

Here, perhaps, the old and often recurring question may be asked, (not however by scholars,) *of what use would it be, even if practicable, to ascertain the true pronunciation of the Greek Language?* With every lover of learning it would be a sufficient answer to say, that the fact itself, like any other thus ascertained, would gratify a liberal curiosity, by settling a long contested point in the literature of one of the most interesting nations of antiquity. It may be added, however, that it would afford us the substantial advantage of putting within our power the means of tracing the etymologies of modern languages through the *oral* as well as *written* part of this admirable tongue, the influence of which has been felt among so many nations. It would also give a new interest to the study of Greek; for every man, who has attempted to acquire a language, feels with how much greater satisfaction he pursues the study of it, when he knows how to *pronounce* it, than when he is obliged, like the unfortunate deaf and dumb, to study merely its *written characters*. In truth, with all nations, except the singular people of China, the whole power of

a language is believed to be in the *oral* part of it, or the pronunciation;* and a scholar hardly feels satisfied, that he knows a language, till he has learned its pronunciation. But to all speculations on this point it is an answer, the force of which every scholar will feel, that could we but bring before our eyes the orator of Greece, and hear with our own ears the accents of that tongue, which swayed the destinies of his country, we should not stop to inquire, of what use it would be to know the pronunciation of the language which fell from it.

It may, perhaps, be thought that we cannot at this day satisfactorily ascertain the ancient pronunciation of Greek. It must undoubtedly be admitted, that we cannot arrive at all the delicate distinctions of accent, (as it is commonly called,) which few but *natives* ever acquire, even with the aid of a living instructer;—distinctions, which change from one age to another in all nations. Such alterations have probably taken place in the successive periods of the *Greek* language. But, that the *general pronunciation*

* "The Chinese (says Mr. Duponceau) consider the mode of conveying ideas to the mind through the eye, by means of written signs, as far superior to spoken words which communicate perceptions through the ear. 'The people of *Fan*, say they, (meaning the Europeans,) prefer sounds, and what they obtain enters by the ear; the Chinese prefer beautiful characters, and what they obtain enters by the eye.' 'It is, indeed, says Remusat, impossible to express in any language, the energy of those picturesque characters, which exhibit to the eye, instead of barren and arbitrary sounds, the objects themselves, figured and represented by their most characteristic traits, so that it would require several phrases to express the signification of a single word.'" *See the learned and philosophical* Memoir on English Phonology, *published in the* *Transactions of the Philosophical Society at Philadelphia*, by Mr. Duponceau; *who cites, for the first of these quotations, Morrison's Chinese Dict. Introd.* p. vii.; *and, for the other,* Remusat, p. 56.

of this language has undergone any essential change in the course of eighteen centuries, I cannot believe to be the fact. On the contrary, I think it can be very satisfactorily shown, that little alteration has taken place even in that length of time. By adopting, therefore, the pronunciation of the present day, we can, as mathematicians express it, approximate very nearly to that of ancient times. How far preferable this would be to our barbarous custom of pronouncing Greek just as we do our own language, I need not stop to remark. This custom, indeed, our English brethren, as well as ourselves, justify by the example of the European nations in general, who have adopted a similar practice. But this justification rests upon a palpable fallacy; for, defensible as the rule may be in the case of other nations, it is not applicable to those who speak the *English* language. The pronunciation of the *English* letters, particularly of the vowels, is essentially different from that of the other European languages; the principal sounds of which are undoubtedly much the same with those of the Latin and Greek. The same rule, therefore, which may be a very good one for the nations of the *continent of Europe*, will be a very fallacious one for Englishmen.

In the case of another ancient language, I mean the Hebrew, we are very well satisfied with making such an approximation; (for that we do no more than approximate in this instance will not be contested,) and, by means of the Masoretic points, we have among the learned of all nations a uniform pronunciation of Hebrew, which may be traced back to a very ancient date. This pronunciation, it is true, was for a time discountenanced by Masclef and his followers, who attempted to introduce what was thought to be an improved method; and the innovation was fa-

vourably received in our mother country, as well as by ourselves, and at one period was even taught at our University. But our scholars are now again following the general practice of the learned in Europe; and they would feel as much ashamed to be ignorant of the pronunciation, as they would of the letters themselves.

Now our means of ascertaining the pronunciation of *Greek*, are not less ample than in the case of the Hebrew language; nay, they are probably more so; for *Hebrew* is admitted by all to be a *dead* language; but *Greek*, though commonly called such, can hardly with strict propriety be ranked in that class; because, though the *form* of it is somewhat changed, or, as we are accustomed to say, corrupted, yet the *body and substance* of it, (I mean among the people of education,) and therefore probably the *pronunciation* too, have been transmitted from one age to another down to our own times, by the same unmixed race of people, who have always spoken it, and as the *same language*. Certain it is, that the pronunciation has undergone no perceptible change since the taking of Constantinople by the Turks, (nearly four hundred yeas ago,) from which period it may be traced back to the eleventh century with a very high degree of certainty; and many facts conspire to show, that no material change had taken place for the seven or eight preceding centuries.

At the period of the taking of Constantinople, the learned and accomplished Greeks, who are well known by the honourable appellation of *the Restorers of Learning*, and who were compelled to seek refuge in *Europe* from the oppression of their Turkish masters, taught their native language with their *native pronunciation;* and their European disciples at that time would no soon-

er have called in question the correctness of it, than they would have done that of a Frenchman, or a German, who should have instructed them in either of their languages. We find accordingly, that Erasmus himself, but a short time before he ventured to condemn the pronunciation of the day, when desirous of obtaining a professor of Greek for the University of Louvain, wrote to *John Lascaris* at Constantinople for a *native* Greek to fill that office. In his letter to Lascaris, after mentioning the establishment of the College, which was founded at Louvain by the munificence of *Busleyden*, and informing him, that the *Hebrew* and *Latin* professorships were already filled, he adds—" Many persons here are seeking for the *Greek* professorship. But my opinion has always been, that we should send for a *native Greek*, from whom the students might at once acquire the *genuine pronunciation* of the Greek Language; and this opinion is acceded to by all, who have the management of this business. They have accordingly directed me, on their behalf, to send for such a man as I should think qualified for the office. Relying, therefore, on your obliging disposition towards me, and on your regard for the cause of learning, I beg of you, if you know of any person, who in your opinion will do honour to us both, that you would direct him to hasten to this place immediately."*

* It will not be uninteresting to the friends of literature, to see the whole of this letter; which records, at the same time, the fact I have mentioned, and an illustrious example of liberality in the cause of learning; and, as the collection of *Erasmus' Letters* is not common in this country, I shall here insert it at large:

" *Joanni Lascari Constantinopolitano Erasmus Roterodamus S. D.* Vir omnibus ornamentis clarissime, *Hieronymus Buslidius*, homo doctus ac potens, et hujus regni decus incomparabile, in itinere Hispanico moriens, legavit multa millia ducatorum ad institutionem novi Collegii apud Lovanium, Academiam hac

The truth is, that *Greek* was not then considered as a *dead* language; nor had it, among the people of education, departed much from the standard of the first periods of the Christian era.* Indeed, if we may take literally the glowing description given by *Philelphus*, a learned Italian, who was naturalized at Constantinople about thirty years before the Turkish conquest, the Greek language at that period was not only *spoken* but *written* in all its

ætate cum primis florentem, in quo publicitùs et *gratis* tradantur tres linguæ, *Hebraica*, *Græca*, *Latina*, salario satis magnifico circiter septuaginta ducatorum, quod tamen augeri possit pro ratione personæ. *Hebræus* jam adest, et item *Latinus*. *Græcam* professionem complures ambiunt. *Verùm meum consilium semper fuit, ut asciscеretur* Græcus natus, *unde statim germanam Græci sermonis pronunciationem imbibant auditores.* Ac meæ sententiæ subscribunt autores hujus negotii omnes, mihique mandârunt, ut suis verbis accerserem, quem judicassem ad hoc negotii idoneum. Quare te rogo, vel pro solita tua erga nos humanitate, vel pro tuo erga bonas literas favore, siquem nôsti, quem existimes et mihi et tibi futurum honori, cura ut quamprimùm huc advolet. Dabitur viaticum, dabitur salarium, dabitur locus. Erit illi res cum viris integerrimis et humanissimis. Neque minus fidat his meis literis, quàm si centum diplomatis res esset transacta. Inter bonos et absque syngraphis bene agitur. Tu cura ut deligas idoneum, ego curabo ne hominem huc venisse poeniteat. Bene vale, doctissime clarissimeque vir. *Lovanii*, postridie divi Marci, Anno M.D.XVIII." (*Erasmi Epist.* 181. *fol. Lond.* 1642.)

* "As early as the sixth century, (says *Harris*, the author of *Hermes*,) or the seventh at farthest, *Latin* ceased to be the common language of Rome, whereas *Greek was spoken* with competent purity in Constantinople, even to the fifteenth century, when that city was taken by the Turks." *Harris' Philological Inquiries, part* ii. ch. 2. Dr. *Gillies* also remarks—"The Greek was spoken in the middle of the fifteenth century, when Constantinople was taken by the Turks; so that from the time of Homer, it subsisted with little variation as a *living tongue* for two thousand four hundred years."—*Gillies' Hist. of Greece*, vol. iv. p. 398. Note 59.

ancient purity and elegance. "The *vulgar speech* (says Philelphus) has been depraved and infected by the multitude of strangers and merchants, who every day flock to the city and mingle with the inhabitants. It is from the disciples of such a school, that the Latin language received the versions of Aristotle and Plato; so obscure in sense, and in spirit so poor. But the Greeks, who have escaped the contagion, are those whom we follow; and they alone are worthy of our imitation. In familiar discourse, they still speak the tongue of Aristophanes and Euripides, of the historians and philosophers of Athens; and the style of their writings is still more elaborate and correct. The persons, who, by their birth and offices, are attached to the Byzantine Court, are those who maintain, with the least alloy, the ancient standard of elegance and purity; and the native graces of language most conspicuously shine among the noble matrons, who are excluded from all intercourse with foreigners. With foreigners, do I say? They live retired and sequestered from the eyes of their fellow citizens. Seldom are they seen in the streets; and when they leave their houses, it is in the dusk of the evening, on visits to the churches and their nearest kindred. On these occasions they are on horseback, covered with a veil, and encompassed by their parents, their husbands, or their servants."*

The pronunciation, which the Greek exiles thus introduced among the learned of Europe was, as I have remarked, the *native pronunciation* of that age. It should also be remembered, that

* See *Hody's* learned work *De Græcis Illustribus Linguæ Græcæ Literarumque Humaniorum Instauratoribus*, p. 188, for the original of this interesting letter. I have adopted the spirited translation which is to be found in *Gibbon's History*.

it was taught, not by mere illiterate adventurers—not by a class of men, whom Sir *Thomas Smith* contemptuously styles "*nescio qui semi-Turcici et obscuri Græci*"*—nor (as Sir *John Cheke* insinuates, with a degree of credulity and illiberality unworthy of a scholar) by a confederacy of impostors, who had conspired to obscure their language, in order to render it difficult to foreigners, and thus make it the source of greater profit to the teachers of it; a confederacy, which would have been as ridiculously impracticable, as a similar one would be among the teachers of a living language at the present day.† No; it was thus taught by the polite and well-educated nobles and the learned professors of Constantinople; who, being unable to rescue any thing from the wreck of their fortunes, were, like the unhappy exiles of a polite and learned nation in our own times, compelled to resort to the occupation of teaching their language, in order to gain a subsistence; and this pronunciation was then received by the learned throughout Europe, as genuine, and so it continued until the period I am now about to mention.

In the sixteenth century a *new* or *reformed* pronunciation, as it was called, was promulgated by *Erasmus*, and countenanced by some other learned men, and at length received in various parts of Europe. This *new* pronunciation, it was contended, ap-

* *De Recta et Emendata Linguæ Græcæ pronunciatione*; written in 1542, and republished by Havercamp in his *Sylloge Scriptorum qui de Ling. Græc. vera et recta pronunciatione Commentarios reliquerunt*, tom. 2. p. 552, Lugd. Bat. 1740.

† *Cheke*, De Pronuntiatione Græcæ potissimum Linguæ Disputationes cum Stephano Vintoniensi Episcopo; written between 1542 and 1555, and republished by Havercamp in his *Sylloge Scriptorum* above cited, tom. ii. p. 235.

proached nearer than the prevailing one to that of the *ancient* Greeks; and, as it was more conformable to the general pronunciation of the *modern languages* of Europe, and consequently was less difficult to acquire, it soon obtained currency among the learned. This change of pronunciation, if it were not supported by the authority of great names, to a person at all conversant with the powers of the organs of speech, and acquainted with the writings of the Greek grammarians and scholiasts which have come down to us, would appear to have been made upon very insufficient data, and without that comprehensive view of language, which has been taken by the scholars of our own times; who, though not possessing more ability than their illustrious predecessors, yet have the benefit of their labours and many advantages besides, which were not then within the reach of scholars. The manner, in which this change is said to have been introduced, I shall presently relate at large. But it will first be necessary to give a general view of *the pronunciation of the Modern Greeks,* which has been the occasion of so much controversy among European scholars.

The pronunciation of the *modern* Greeks has been supposed to differ from that of their ancestors, both in the *sounds of the letters,* and in being regulated wholly by the *accents,* without regard to what is called *quantity.* The *accents* will be the subject of consideration hereafter; at present I shall confine my remarks to *the sounds of the letters.* In doing this, I shall first present a *general view* of the pronunciation, (which will be found in the following table,) and then give a more particular account of the several letters, when taken single or in combination; and I shall subjoin to each a concise statement of the arguments in favour of the *old,* and of the *new,* or *Erasmic,* pronunciation.

The *Alphabet* is pronounced by the *Modern Greeks* as follows :—

	Names of the letters.	Powers of the letters.	
α	álphah	*a*,	in our word *far ;* commonly called the Italian sound of *a*.
β	véetah	*v*.	
γ	gámmah	*g*.	Before α, ο, ω, the γ sounds as our *g* does before the corresponding English vowels; which is usually called the *hard* sound of *g*. But before ε and ι, and the diphthongs having their sound, it is pronounced like our *y ;* for example, γέρας would be pronounced *yá-ras ;* and γίνομαι, *yéenomay*. Before another γ, or κ, ξ, χ, it takes the sound of *n*.
δ	dhéltah	*dh*,	or (as *Walker* calls it in English) the *flat* sound of *th*, as in our word *this*. The power of the δ may be conveniently represented by *dh*, in order to distinguish it from that of ϑ, which has the *sharp* sound of *th*, as in *thin*.
ε	épsilon	*e*,	in *met*, nearly, or in *there*.
ζ	zéetah	*z*.	
η	eetah	*ee ;*	or like *e* in the word *me ;* but, for distinction's sake, it may be represented by *ee*.
ϑ	théetah	*th*,	in thin. See the remark above on the letter δ.
ι	yótah	*i*	in *machine*, *marine*, &c.
κ	káppah	*k ;*	but before the vowels ε and ι, and the diphthongs having the same sound with those vowels, it partakes of what Walker calls in English, the "softened" sound of the gutturals, as if it were followed by the letter *y*. Thus καὶ is pronounced 'kyá ; δίκαιος, dhée-kyaös.
λ	lámvthah (the *th* being sounded as in the word *this*.)	*l*.	Before α, ε, ο, ω, it has the common English sound of *l ;* but before ι, and υ, and the diphthongs which are pronounced like *ee*, it has the liquid sound of *gl* in *seraglio*, which may be represented by *'ly ;* as in λίμος, and λοίμος, both pronounced *'lyeemos*.*
μ	mee	*m*.	
ν	'nyee	*n*,	before α, ε, ο, ω ; but before ι, υ, ει, &c. it has the sound of *gn* in the foreign words *seignior*, *bagnio*, &c. ; which may be denoted by *'ny*.†

* I do not find this distinction in the sound of λ (depending on the vowel which follows it) noticed by any of the old writers or the modern travellers : But Mr. *Ciclitira* assures me, it is universally observed in Greece. The *Captain* of *The Jerusalem* also uniformly observed it in reading to me.

† This distinction in the sound of the ν appears to be equally unnoticed, by writers and travellers, with that of the λ ; but Mr. C. assures me it also is universal ; and the Captain likewise uniformly observed it.

	Names of the letters.	Powers of the letters	
ξ	ksee	*x*,	(or *ks*) as in *exercise*; but never like *gz*, as in the word *example*, &c.
ο	ómicron	*o*	in *not*, *for*, &c.
π	pee	*p*.	When preceded by μ, it partakes of the sound of *b*; thus ἄμπελος is pronounced nearly as if written *ámbelos*.
ρ	rho	*r*.	
σ	seegmah	*s*.	This should always have the pure sound of s, and never that of *z*.
τ	tahf	*t*.	
υ	ýpsilon (pronounced éepsilon)	*y*,	as in the final syllables in English; for example, in *likely*, *lovely*, &c.
φ	phee	*ph*.	
χ	khee	*kh*,	guttural; like the German *ch* final, or nearly like the Spanish guttural sound of *x*, &c.
ψ	psee	*ps*.	It should be remarked, that the sound of the *p* in this letter is always preserved, both at the beginning and the end of syllables.
ω	oméggah	*o*;	like the *omicron*.

The *diphthongs* are pronounced in the following manner:

αι	like	*ai*	in *pain*; or like *epsilon*.
ει	like	*ei*	in *receive*, or long *e*.
οι	like	*oe*	in *oeconomy*, or long *e*.
υι	like	*ui*	in *guilt*, or more exactly like long *e*.
ου	like	*ou*	in *you*; or *oo*.
αυ	like	*af*	or *av*, according to the nature of the consonant which follows it. For example; if a *sharp* consonant, (as Walker denominates them in English) that is, π, κ, τ, &c. follows, then this diphthong is pronounced *af*; but if a *flat* consonant, as β, γ, δ, &c. follows, then it is pronounced *av*.
ευ	like	*ef* or *ev*, as in the case of αυ.	
ηυ	like	*eev*.	
ωυ	like	*ove* or *ofe*.	

It is only necessary to add in this place a few combinations of consonants. The principal ones are the following:

γγ, pronounced like *ng*. Thus, ἄγγελος is pronounced *áng-gyelos*.

γκ, like *ng*. Thus, ἐγκέφαλος is pronounced *engéphalos*.

μπ, at the beginning of words, like *b*; thus, the name of *Boston* would be written Μπόστον. But this is chiefly used in foreign names.

ντ, at the beginning of words, like *d*: Thus *Dover* would be written Ντόβερ. In *middle* syllables, ντ generally sound like *nd*; but there are some exceptions.

This is the *general pronunciation* of the Modern Greeks, as it is described by travellers, and as I learned it from the Greeks I have mentioned. The niceties, which distinguish the people of different provinces from each other, need not be regarded by foreigners. The purest Greek, it is admitted by all writers, is that which is spoken by people of the first class in Constantinople; and this is confirmed to me by Mr. Ciclitira, who has spent much of his life in that capital. I need not stop to remark, that *ancient* Greek (which has been used in their Church-Service from the first ages of Christianity to the present day) is pronounced by them in the same manner as the *modern*.

From this general view of the pronunciation it will be perceived, that many of the vowels and diphthongs are pronounced exactly alike; and hence superficial observers will be ready to ask, as was done in the days of Erasmus, how it is possible to distinguish these different letters, and thus determine what words are made use of by any one, that should address us with this kind of pronunciation. Instead of giving an answer of my own, I shall give that of a native Greek to the same question, proposed to him by a well known English scholar two centuries ago, as it is related in the following anecdote; which, as it is to be found only in a work not very common in this country, I will give at large. The anecdote is to be met with in the *Observations* subjoined to the edition of the *Poetæ Minores Græci*, published by Ralph Winterton, the well known professor in the University of Cambridge. After making some observations upon the corruptions of Greek Manuscripts, (occasioned by the confounding of letters which had the same sounds,) Winterton says—

"This brings to my mind a certain Greek, with whom I conversed soon after I came to the University. Upon my first meeting him, he put my ears to the torture by a pronunciation altogether unheard of by me till that time; for, when I asked him something, which I do not now recollect, he replied, like a person that did not understand what I had said, by asking—*τί μι λέγις κίριε.* I was equally at a loss to know what he said, and I requested him to write it down, which he did with perfect correctness as to orthography, thus—*τί μοι λέγεις, κύριε.* I praised his *orthography*, but censured his *pronunciation.* He, on the other hand, condemned *my* pronunciation as coarse and rustic; for I pronounced according to our custom, *Ty moi legeis, kurie;* which, as soon as he had heard, he could not refrain from laughing, and said to me—*προφέρις ἀγρίκως πῶς*, that is, you pronounce in a rustic manner: *Ἄκυσον, κίριε· δῖ ὕτω προφέριν, ἀστίως πως*, (I write as he pronounced) Hear me, Sir, you ought to *pronounce* as the people in cities (or polite people) do; thus, *τί μι λέγις, κίριε, ἄλλως δε γράφιν*, but you must *write* differently, thus, *τί μοι λέγεις, κύριε.* I then proceeded to request him to write down the pronunciation of the vowels and diphthongs, which he did after this manner—

$$\text{Δεῖ προφέρειν}\quad \begin{matrix}\text{τὸ}\\ \\ \text{τὴν}\\ \\ \end{matrix}\left\{\begin{matrix}\eta\\ \upsilon\\ \varepsilon\iota\\ o\iota\end{matrix}\right\}\ \text{ὡς ι, οἷον}\left\{\begin{matrix}\tau\eta\\ \tau\upsilon\\ \tau\varepsilon\iota\\ \tau o\iota\end{matrix}\right\}\tau\iota.$$

$$\text{τὴν}\{\alpha\iota\}\ \text{ὡς ε, οἷον}\ \{\tau\alpha\iota\}\tau\varepsilon.$$

By this method I began to comprehend him with ease, when he pronounced according to his manner. I continued thus: *Πῶς οὖν διαφέρει ταῦτα ἀλλήλων, ἡμεῖς καὶ ὑμεῖς; ἢ πῶς διαγνοίη*

τις ἄν, ἐι δεῖ ὁμοίως προφέρειν, ἱμῖς, ἱμῖς; How then do these words *ἡμεῖς* and *ὑμεῖς* differ from each other, or how could any person distinguish them, if we must pronounce them both *ἱμῖς, ἱμῖς*? He replied—*δία τῆς συντάξεως, THia tis sintaxeos, ἱμῖς λέγομεν, ἱμῖς λέγετε,*—by the syntax, or construction of the sentence." This satisfactory answer, which was just such as Winterton himself would have given to the Greek, if he had asked a similar question about the *English* language, put an end to the dialogue. A more satisfactory one, indeed, could not have been given; and, if we were not in the habit of overlooking what is immediately before our eyes, it would appear surprising, that such an objection should ever have been made to this pronunciation; and by Englishmen too, whose language has a large share of what foreigners consider as absurdities arising from this very cause. With how much force could this Greek, if he had been acquainted with our language, have retorted the question, by saying—In *English* you have as many different letters to denote *similar sounds*, as we have in Greek; and how do you distinguish words which have the *same sound* but *different meanings* in English? For example; this very sound of *e* long, you express in a greater number of ways than we do in Greek;—

by æ, as in *Cæsar*, &c.

e, as in *scene, mete*, &c.

ee, as in *see, sees, seen, meet.*

ea, as in *sea, seas, meat, mean.*

ei, as in *seize, deceit, conceive.*

ie, as in *belief, chief, mien.*

i, as in *marine, fatigue, invalid*, &c.

To say nothing of the few words in which *eo, oe, eg* and *ua* have

this same sound. And if we take into view the *unaccented* syllables of English words, we find, that the whole list of vowels *a, e, i, o, u, y,* and some of the diphthongs are, in a great part of your language pronounced exactly alike!*

Such would have been the reasoning of this Greek in respect to the *English* language: And if we ourselves turn our attention for a moment to any foreign language, the *French,* for example, where innumerable words and phrases of different significations have precisely the same sound, and, though different to the eye are the same to the ear, we shall be much more forcibly struck with the futility of this objection. How absurd does it appear to us, for instance, that *é, ai, oi, ait, oit, aient* and *oient* in that language should all have the same sound, that of the letter *a* in English. How, again we may ask (as Winterton did the Greek) could any one distinguish in French between *the third person singular* and the *third person plural* of nearly all the verbs in the language, (except those which begin with a vowel or *h* mute, or which are followed by words that begin with those letters,) which are so frequently recurring in speaking the language? To descend to particulars; how could any one determine when a Frenchman means to say, *he* should be, (*il* seroit,) or *they* should be, (*ils* seroient,) *he* speaks, (il parle,) or *they* speak, (ils parlent,) *he* was speaking, (il parloit,) or *they* were speaking, (ils parloient,) &c. with innumerable other expressions, which occur in every French sentence he utters? The answer is obvious; *by the construction,* as the Greek observed to Winterton; or in other words,

* I have been the better enabled to collect these various combinations of letters in our own language, by the aid of the *Memoir* of Mr. *Duponceau,* on *English Phonology,* before cited.

by *use and familiarity with the language.* Need it be remarked, that *Frenchmen* understand each other, and that the *Modern Greeks* do the same, notwithstanding these ambiguities, just as well as we do each other in our language? And can there be a doubt, that the Greeks of *ancient* times must have understood each other with just the same ease, that their descendants do, let their pronunciation have been as irregular, as the human mind can imagine it to have been? But, to return to the controversy alluded to.

Such, as I have above observed, was the pronunciation of Greek universally adopted in Europe, until the age of Erasmus; when that illustrious scholar promulgated a new or "reformed" pronunciation, which was afterwards called by his name. The occasion of his introducing this *reform,* as it was called, is certainly one of the most singular occurrences in the history of literature; but, singular as it may appear, it rests upon testimony hitherto unimpeached; and the biographers of Erasmus, as well as other writers, who mention the fact, do not attempt directly to controvert it. The anecdote seems to have been first published by *Gerard Vossius;* but I shall here give it (in a translation) with the accompanying remarks of *John Rodolph Wetstein,* and *John Michael Langius;* the latter of whom published it in his *Exercitationes Philologicæ de differentia Linguæ Græcorum Veteris et Novæ sive Barbaro-Græcæ.* This same account was afterwards republished by Havercamp, by way of preface to his edition of the concise but satisfactory treatise of *Erasmus Schmidt* on the pronunciation of the Greek Language.*

* Havercamp, Sylloge. Scriptorum &c. tom. ii. p. 626.

"We distinguish (says Langius) the pronunciation of Greek as the *Reuchlinian* or ancient, and the *Erasmic* or new; which latter is mostly used in our schools at the present day. The former takes its name from *John Reuchlin* of Phorca, (who died in 1521,)* because that very learned man was the first among the Germans, who was so much distinguished for his knowledge of Greek, that *Argyropylus*, a native Greek, upon hearing him speak the language, exclaimed, *that Greece had taken her flight across the Alps;* and it was from *Reuchlin* that the Greek scholars of this country [Germany] received their first pronunciation of the language; which was similar to that of the *Modern Greeks. Erasmus*, however, in consequence of an amusing incident, introduced that new-fangled pronunciation (unknown to the natives of Greece) which is now adopted in our schools, and is called, from its author, the *Erasmic* pronunciation. People now began, contrary to the custom of the ancients, to pronounce the letter β as *B* in the Latin language is commonly sounded; the letter η they made equivalent to *E* long; the diphthongs αι, ει, οι, they twisted in an execrable manner, and with a harsh sound almost into two distinct vowels; with many other conceits of the kind. But I will relate the whole story in the words of the celebrated *John Rodolph Wetstein*, as it is to be found in his *Orationes Apologeticæ pro Græca et Genuina linguæ Græcæ pronunciatione*, p. 119. 'Let us see, says he, what opinion we ought to entertain of this new Pandora; and whether she received all her endowments and attractions from the Gods, or whether in truth

* *Reuchlin's* name in German signifies *smoke;* and, according to the fashion of the day, it was *Latinized* into *Capnio;* by which he is more commonly mentioned in the works of that period.

she has not in some measure imposed upon her suitors by counterfeit charms. The garb, indeed, in which she is introduced to us, and by great names too, has the exterior of *antiquity;* but if we accurately examine this personage, we shall discover that she is of *modern* origin, and was introduced into the world by a signal fraud. Her parent was that phœnix of literature, the great Erasmus; who, in his *Dialogue on Pronunciation,* was the first person that dared to decide, how far the several letters had departed from their ancient sounds, and to point out by what means we might get back to the ancient purity. But that sage would never have gone such lengths as he did, had he not been led into a snare (and who, that is not more than human, is proof against such things?) by a trick of his friends; as will be seen in the following narrative, which you shall have in the words of the illustrious *Vossius,* who gives it upon the authority of *Henry Coracopetrœus.** 'I heard *M. Rutgerus Reschius,* (says he,) who was professor of Greek in the *Busleiden* college and my revered preceptor, relate, that he was in the Liliensian seminary at the same time with Erasmus, who occupied an upper room and himself a lower one; that *Henry Glareanus* happened to arrive at Louvain from Paris and was invited to dine in the college; and when Glareanus was asked, what news he brought with him, he answered, (which was a story he had made up on the way, because he knew Erasmus to be over-fond of novelties and wonderfully credulous,) that certain native Greeks had arrived in Paris, who were men of great learning, and who used a pronunciation of the Greek Language entirely different from that, which prevailed in these parts;

* *Henry Ravensberg,* whom Vossius calls—"viri egregie docti, doctisque perfamiliaris." See *Havercamp's Sylloge,* tom. ii. p. 628.

as for instance, instead of calling *β*, *veetah,* they called it *batah;* for *η*, *eetah,* they said *atah;* for *αι* [sounded *a*] they said *aye;* for *οι* [sounded *ee*] they said *oy*, &c.* As soon as Erasmus heard this account, he wrote his *Dialogue* on the true pronunciation of the Greek and Latin languages, that he might appear to be the discoverer of this new method, and offered the work to *Peter*, a printer, at *Alost,* in order to have it published; but the printer declined doing it, either because he was engaged in other works, or because he could not undertake to publish it so soon as was desired, and Erasmus then sent the work to *Froben,* at Basle, by whom it was printed and immediately published. *Erasmus,* however, having discovered that a trick had been practised upon him, never afterwards used that pronunciation himself, nor did he direct his friends to adopt it. In proof of these facts, *M. Rutgerus* used to show, in Erasmus' own hand-writing, a manuscript system of pronunciation drawn up for the use of *Damian de Goez,* a Spaniard, Portuguese which was not at all different from that adopted in all places where the language is used, both by the learned and the unlearned.'† '*Erasmus himself* (continues *Wetstein*) had no faith in his own Dialogue. Who then shall require me to believe in it?

* The original is—Eos nempe sonare pro B *vita, beta;* pro H *ita, eta;* pro *αι* æ, AI; pro *οι* *i, oi* et sic in cæteris.

† "Ipsius Erasmi manuscriptam, in gratiam Damiani a Goes Hispani pronunciationis formulam" &c. After the words *pronunciationis formulam* there is, as Havercamp remarks, in the original of Vossius, this parenthesis—" *(cujus exemplar adhuc apud me est.)* Schedæ autem qua superiora narrantur, nequis ei fidem detraheret hoc modo, teste Vossio, subscribitur: *Henricus Coracopetræus Cuccensis,* Neomagi. cIↄ Iↄ lxix. *pridie Simonis et Judæ.* Hanc schedam, scriptam olim manu H. Coracopetræi, viri egregie docti, habere se profitetur, isto loco, Vossius."

That he continued to follow the prevailing mode of pronouncing, is apparent from his familiar *Colloquies*, particularly that which is called *Echo;* where, to the word *erudit*ionis, Echo makes a response by ὄνοις; to *epis*copi, by κόποι; to *ario*lari, by λάροι; to *astro*logi, by λόγοι; to *grammat*ici, by εἰκῆ; to *fameli*ci, by λύκοι; every one of which corresponds with the common pronunciation of Greek; which, if he had known it to be erroneous, he would undoubtedly in his subsequent editions have taken pains to correct: But so far from this, he not only adhered to it himself, but took particular care, that it should be taught to those, who were entrusted to his charge."

Such then, it should seem from this narrative, was the origin of the "*new*" or "*reformed*" pronunciation of the Greek language. The anecdote rests upon the authority of *Coracopetrœus;* and doubts have been entertained, by some persons, of its authenticity. But those doubts appear to be founded, rather upon the singularity of the occurrence, than upon any want of credibility in the witness; for his character stands unimpeached, and the fact does not appear to have been questioned by the writers who lived nearest to that period. *Gerard John Vossius*, (who lived within a century after *Coracopetrœus*,) a staunch Erasmian and sufficiently inclined to detect the falsehood of the story, if it were false, does not call it in question; but, on the contrary, speaks of it as a circumstance not known to many persons, and thinks it important to lay it before his readers, in order to make them acquainted with the motives, which impelled Erasmus to write on this subject;* and he endeavours to account for Eras-

* "Erasmus, qua occasione ad scribendum de Recta Pronunciatione fuerit impulsus, paucis cognitum arbitror. Itaque visum hac de re adjicere quod in

mus' not adhering to his new pronunciation himself, by supposing, that he abandoned it in consequence of the difficulty of overcoming his old habits, and of making the public follow him in his innovations, however well founded they might be.* Nor does *Havercamp* (who was also an advocate for the Erasmian pronunciation, and from whom, as the editor of the controversial tracts on this queston, we should naturally have expected an investigation of the truth of the narrative,) venture to deny it; but contents himself with remarking, that *he does not wish to discuss the credibility of the testimony of Coracopetræus*—" de cujus testimonii veritate (says he) disputare nolumus." The narrative is also republished from Vossius by *Jortin*, in his life of Erasmus, without any intimation, that I have observed, of its being questionable.

That such a change, however, in the pronunciation of the Greek language should have been thus effected, seems at first view hardly possible. But when we consider, that by this change *Greek* was more assimilated to the languages of Europe in general, and consequently became more easy to the learner; and when we reflect upon the great influence of names at that period—

scheda quadam habeo, scripta olim manu *Henrici Coracopetræi*, viri egregie docti, doctisque perfamiliaris. Ea ita habet &c. and then Vossius relates the story at large.

* "Verum cum Achillea sint pleraque omnia quibus ab Erasmo atque aliis refellitur vulgaris isthæc loquendi ratio, neutiquam in animum inducere possum, quod Erasmus cam retinuerit, nec amicos ab ca deterruerit, id eo factum, quod editi libelli pœniteret; verum magis mihi verisimile fit, cum meliora videret probaretque, deteriora tamen sequutum; sive quid a puero sic loqui adsuevisset; sive quod desperaret suo se exemplo alios ad imitationem provocare posse; sive quod loquendum putarit cum vulgo, sapiendum cum paucis, ut præcepit τῆς ἀληθείας Philosophus." Vossu *Aristarch*, lib. i. c. 28.

of names too, which would scarcely have less authority in our own times, it will cease to appear extraordinary. And, as the *ancient Greek* was not studied for the purposes of conversation, the learned were willing to spare themselves the labour of studying its pronunciation. When, therefore, the idea was once published among Europeans of speaking Greek, as they did their own languages, and that method was defended too, as being nearer to the ancient, the contagion spread, and the pronunciation of the modern Greeks was by degrees neglected. The "*new*" pronunciation, however, was not received at first with much favour; so far from it, that a warm controversy arose among the principal scholars of that day, of which I shall incidentally give some account as I proceed; for a controversy, conducted by such distinguished advocates, cannot fail of being interesting to us, even after the lapse of several centuries. Whether, indeed, the anecdote above related of Erasmus is true or not, is of little consequence as to the merits of the present question. We can employ ourselves more usefully in examining the arguments, which were urged by him and his friends in support of their innovation, and the answers which were made by their adversaries; and this I shall now proceed to do, with as much conciseness as possible, from the principal writers in the controvery; adding such further observations, as are furnished by the researches and discoveries of our own times. In doing this, it will be most convenient to follow the order of the Alphabet.

A.

The pronunciation of the letter *α* is undisputed. All scholars agree, that it was sounded by the *ancient* Greeks as it is by their descendants, and by all the nations of Europe at this day, except the English; that is, like what we call the Italian *a*, in our word *father*, &c. which sound, by itself, we should express in English by *ah*. It will not be uninteresting to see how minutely it is described by *Dionysius of Halicarnassus*: Ἀυτῶν δὲ τῶν μακρῶν ἐυφωνότατον τὸ α, ὅταν ἐκτείνηται· λέγεται γὰρ ἀνοιγομένου τοῦ στόματος ἐπὶ πλεῖστον, καὶ τοῦ πνεύματος ἄνω φερομένου πρὸς τὸν οὐρανόν: Of the long [vowels] *α* is the most sonorous, when it is prolonged (or a stress is laid upon it;) for it is uttered with the mouth wide open, the breath being at the same time impelled upwards towards the roof of the mouth.*

B.

The ancient pronunciation of the letter *Beta* has been the subject of much controversy. The *Modern Greeks* pronounce it like our *V*, and call its name βῆτα, *veetah*; the followers of *Erasmus* on the other hand assert, that it should be pronounced like the Roman *B*, which, they at the same time contend, was anciently sounded in *Latin*, just as it is in *Italian* and other modern languages; but the correctness of this latter opinion, we shall find, there are many strong reasons for doubting.

The first, and principal argument of Erasmus (who indeed did not support his opinions on this subject with such an array of authorities as some of his followers) is founded upon a well known

* Dionys. Hal. de Structura Orationis, sect. 14. edit. Upton, p. 94.

passage in one of *Cicero's* letters, where there are some remarks upon *equivoques;* among which Cicero mentions the word *bini,* (sounded, as Erasmus takes for granted, *beenee)* which in *Latin* has a different signification from βινει in Greek. Now, says Erasmus, if the Greek word was pronounced by the *ancient,* as it is by the *Modern* Greeks, *veenee,* the *Latin* word and the *Greek* one could not have been enough alike in sound, to have given room for a double meaning, any more than the two words *bini* and *vini* could have done in the *Latin* language. The same argument was afterwards much relied on by other writers in the controversy; the chief of whom were—*James Ceratinus,* a learned Dutchman, who in 1529 dedicated to Erasmus a short treatise on the Pronunciation of Greek*—*Theodore Beza*—and *Henry Stephens;* to which number should be added *Adolphus Mekerchus (Metkerke);* whose treatise, however, is so gross a plagiarism from *Beza's,* that the editor, *Havercamp,* feels it to be a stain upon the Belgian character; and he feebly excuses it by remarking, that *Henry Stephens,* no very forgiving censor, had pardoned *Metkerke,* and (as is the fact) had made use of his strong arguments himself. Let us now see what answer may be given to the argument from Cicero.

Of the several writers, whose tracts in this controversy have been published by *Havercamp,* in his *Sylloge Scriptorum* before cited, there are three in defence of the pronunciation of the *Modern Greeks;* they are—*Gardiner,* the well known Bishop of Winchester and Chancellor of the University of Cambridge, who

* *Ceratinus'* family name, according to the biographers, was *Tryng;* he was born at *Hoorn* or *Horn* in Holland; whence, according to the fashion of the age, he formed his name of *Ceratinus,* through the Greek κέρας, a horn.

wrote with no contemptible ability in reply to Sir *John Cheke,* and by an Edict as head of the University, positively forbade the teaching of the new or Erasmian method; *Gregory Martin,* who made a learned reply to *Mekerchus;* and *Erasmus Schmidt,* a German, whose concise, but learned and able treatise will be more particularly noticed in the course of this inquiry. Of these three writers, *Martin* alone seems to have attempted (and that not with complete success) to answer specifically the argument from Cicero. He agrees with *Mekerchus,* that the *Latin* and *Greek* words are made *alike in sound* by Cicero; but he asks him to point out, in what part of them the similarity exists. "Si tu pugnes (says he) de β, quod sonandum sit ut *B,* ego de ει contendo, quod in eodem loco pronuncietur ut *i,*" &c. "If you contend, that the resemblance in sound lies in the β, which is therefore to be pronounced like *b,* I maintain that it lies in the ει, which is to be pronounced like the letter *i.* If you reply, that the letter *i* among the Romans sounded like ει, take care lest, while you are over-solicitous to make them alike, you inadvertently establish a difference between them. For βινει in Greek you yourself, I presume, read *binei;* but *bini* in *Latin,* according to your own opinion also, must be read *beinei;* so that there is a marked distinction between the two."* The argument thus far does not seem by any means satisfactory; for if, as he contended (and as was the case) the ει and *i* were alike in *sound* but differed only in *quantity* still unless the Greek β and the Latin *B* very closely resembled each other, there could hardly have been room for

Gregor. Martin, De Græcarum Literarum Pronunciatione *ap. Havercamp. Syllog.* tom. ii. p. 587.

an *equivoque* that would be endured even by the gross ear of a foreigner, as Cicero was in respect to the *Greek* language. That there was such a resemblance can now be more satisfactorily shown, than it could have been at the time when *Martin* wrote; but the resemblance probably must have consisted in this, that the Roman *B* and the Greek β were sounded rather like the letter *V*, than the *B*, of modern languages. That the Roman *B* had that sound for a long period, is manifest from its being perpetually confounded with it in writing. Martin, indeed, intimates that he thought something of this kind probable—"Superest alia *conjectura* (says he) quando jam ista necessario confundenda sint, ut dicamus *b* olim priscis Romanis aspiratè magis sonuisse quam nunc: non tamen ut in *V* consonante fit, labiis valde apertis, sed conjunctis magis et compressis, ut sit quasi *bvini* dissyllabum, quod hodie quoque apud Burgenses fit in Hispania, qui *vestia* pro *bestia*, *vene* pro *bene* exiguo admodum vocum discrimine pronunciant."

If *Martin* had been in possession of all the information, which the researches of later scholars have brought to light, he would not have expressed himself with so much hesitation on this point. He might have stated it not merely as a "conjecture," but as an opinion supported by very strong evidence, that the Romans did for a long period pronounce their *B* so nearly like *V*, as in general not to be distinguishable from it, at least by the ears of foreigners; just as is the case with the *Spaniards* at the present day.* In proof of this, it will suffice to refer to the authorities

* I have often thought it probable, that the *Spaniards* and *Portuguese*, who were a Roman colony, may have retained more of the ancient masculine pronunciation of the Romans, though tinctured perhaps with a *provincial* rusticity, than is

collected in *Heineccius'* elaborate edition of the well known work of *Brissonius, De Verborum quæ ad Jus Civile pertinent significatione*: A multitude of other instances may be found in *Gruter,* and other writers on Roman antiquities.

"*B*, secunda alphabeti apud Latinos litera. Quum vero illa *Græcorum* βῆτα *respondeat,* hæc autem litera a Græcis ita pronuncietur ut ea et *V* Latinorum exprimere soleant, e. g. Βηΐοι pro *Veiis* apud Plutarch. in Camill. p. 129. λίβιος pro *Livio,* apud eumd. in Romulo, p. 36. φλαβία pro *Flavia, apud Reines. Inscr.* adpend. p. 35. factum inde est, ut in vetustis monimentis, maxime quæ a seculo quarto prodierunt *fere perpetua sit literarum B et V permutatio.* Hinc in marmoribus apud Gruter, p. DCLXXXI, 7. VIVIANUS legitur pro *Vibiano* apud *Reines. Inscr.* I, 45, BICTORINVS pro *Victorino;* apud *Gruter,* p. DCCXVIII, 6, ABITA pro *Avita,* in l. 11. C. *Theod. de Cohortat.* VASTAGA pro *Bastaga:* Ut innumera alia præteream, inter quæ etiam est ridiculum illud a V. C. Ev. Ottone observatum apud Fabrett. p. 546. CONIVGI BENE BIBENTI, pro *Bene Viventi.*"

From these instances and others, (which go back to a period but little subsequent to the age of Cicero himself,) it will appear, that for many ages there was little or no difference, in the ordinary pronunciation, between the *B* and the *V* of the Romans; and

to be found even in *Italy* itself; for the Latin language throughout *Italy,* which was the great theatre of the operations of their enemies, the Goths, must have been much corrupted by the constant and immediate influence of the language of those invaders; while the *provinces of Spain and Portugal,* being remote from that influence, might preserve the language, which they originally received from their Roman masters, in greater purity than the people of Italy.

consequently, between the Roman *B* and the Greek *Beta*. Perhaps their true sound was one between our *V* and *W*, like the *W* in German; which would be formed by barely touching the upper teeth to the lower lip, instead of pressing them so strongly upon it as we are accustomed to do in pronouncing our *V*. That the Roman *B*, however, suffered some slight changes in sound at different periods, is not improbable; and it might be hazardous to assert, that in the age of *Cicero*, it had exactly the same sound, which was given to it three or four centuries afterwards, when we find the incriptions above referred to. If, however, we ascertain the pronunciation, which was used even at this latter period, it would be sufficiently near to that of the Augustan age, to satisfy the most fastidious ears of foreigners.*

Another argument of *Erasmus* is, the common, though very inconclusive one, founded on the etymologies of *Latin* words from the Greek; as that *βοῦς* in Greek becomes *bos* in Latin; *βοᾶν*, *boare*; *τυρβᾶν*, *turbare*; *βαλανεῖον*, *balucum*, etc.† This also rests upon the assumption, that the Latin *B* and Greek *β* were both sounded like the modern *B*; which, as we have just seen, for

* Since these remarks were written, I have obtained a copy of the *Herculanensia, or Archeological and Philological Dissertations*, by *Drummond & Walpole*; by means of which interesting work, the evidence of the similarity of the Roman *B* and *V* is now carried back to the Augustan age. In the *tenth Dissertation* the author (Walpole) observes—"*Capacio* has published some *Latin* inscriptions which were found at Herculaneum, without any comments on them. I shall point out what appears to be worthy of notice in them. In the first inscription we have *devitum* for *debitum*." The author then also adds—"I find the changes of *B* and *V* very common in the *early Christian* inscriptions, as BIXIT for *Vixit*; BIRGO for *Virgo*." p. 172.

† Erasm. Dialog. p. 122.

a very long period, was not the case. But we can also, on the other hand, find a great number of Latin words, beginning with *V*, which are derived from Greek ones begining with β; as *vado* from βάδω, *volo* from βέλομαι, *via* from βια, etc. which (to apply this reasoning) would prove that the Greek β and Roman *V* sounded alike.

Equally inconclusive are several other arguments adduced by the writers in this controversy; as, 1. That βῆτα is a *middle* letter between the smooth letter π and the aspirate φ; an appellation, which might properly be applied to it, whether it is to be sounded like *B* or like *V*.* 2. That the very name, *Alphabetum* (which, says Metkerke, nobody pronounces *alphavitum*) shows that *Beta* ought to be sounded like *B*. But this is plainly assuming the thing in question. 3. That *Beta* is derived from the Hebrew *Beth*, by adding *a*; and hence the Greeks, when they write Hebrew or Latin words having a *B* in them, always write them with β, as may be seen in *Plutarch*, *Dion* and others. This argument is liable to the same objections as the others; and it will, moreover, presently be seen, that the argument from the *Hebrew* is directly against the Erasmic pronunciation.

But the argument, which is considered as the most decisive in favour of the Erasmic pronunciation of *Beta* (which was not, however, adduced in Erasmus' Dialogue) is the well known line cited by *Eustathius* from *Cratinus*, to mimic the bleating of a sheep.

Ὁ δ' ηλίθιος ὥσπερ πρόβατον, Βῆ, Βῆ, λέγων βαδίζει.

Now, says *Beza*, after citing this line, if the syllables Βῆ, Βῆ, express the bleating of a sheep, they must have been pronounced

* Beza, p. 311. H. Steph. p. 446. Metkerke, p. 54.

be, be, and not *ve, ve;* that is, (to express in *English* the sounds thus expressed by Beza in Latin) *bay, bay,* and not *vay, vay.*

While I was at college, studying Greek with the aid of no other book than my *Port-Royal Grammar,* (which, with all its excellencies, contains but little on the subject of *pronunciation,* because probably the learned author did not consider that as an essential part of his plan,) I was much struck with this argument; which then appeared to me unanswerable. Further reflection, however, has led me to think, that too much importance has been given to arguments drawn from this and other *animal sounds;* which, as they form no part of any human language, no nation has any settled conventional sign, or word, to express. We accordingly find, therefore, that not only people of different nations, but individuals of the same nation, represent such sounds by letters of very different powers. This did, in fact, happen within my own observation in the case of this very sound; for when I once asked Mr. Ciclitira and Captain Katara (at different times) how they would express it in *Modern Greek,* the former wrote it μπέε, μπέε, that is *bay, bay,* and the latter μέε, μέε, or *may, may;* and perhaps a third would have written it μπάα, μπάα, just as we commmonly do in English, *bah, bah.* But great weight has been attached to this argument, from the days of Erasmus to more modern times; when we find *Gibbon* remarking (though, perhaps, as much for the sake of indulging his spleen against the clergy, as of defending the *reformed* pronunciation) that this "monosyllable βῆ represented to an Attic ear the bleating of sheep; and a belwether is better evidence than a bishop or a chancellor."* I shall, therefore, state at large the answer, which was given to it

* Decline and Fall of the Roman Empire, ch. 66.

three centuries ago by *Erasmus Schmidt*, in the Treatise I have already mentioned.

"As to the bleating of sheep (says he) whose cry is not *bi, bi*, [in *English bee, bee*] but *bê, bê*, [i. e. *bay, bay*,] it must be recollected, that in these and similar words, whose sound is an echo to the sense, we do not express with precision the inarticulate voice of brutes, which indeed itself is not always uniform. Thus the Greeks express the cry of a sheep by βῆ, βῆ, which others express by blä, blä [*blay, blay*,] and the Latins by *ba, ba* [*bah, bah*,] from *balandi*; while others again express it by *ma, ma*, [i. e. *mah, mah*] or *mä, mä*, [i. e. may, may.] It cannot therefore be proved by this, that the η was exactly equivalent to the ε or to the ä or to the α; or that the β is exactly equivalent to the μ. In like manner the Greeks expressed the *barking of a dog* by the verb βαύζειν, whether it is to be pronounced *bau* or *bav*; but the Germans express the same thing by *miffen, meffen, maffen, muffen*, and sometimes by *hau, hau, hau*; thus using different vowels and different consonants. Shall we therefore say, that those letters all have the same power? *Aristophanes* expresses a dog's barking by αὖ, αὖ, that is, either *au, au*, or *av, av*; for different dogs sound it both ways.

"The voice of the *lark* we express by *lir, lir*, whereas that bird modulates its notes rather to the sound of other vowels than the *I*; and the Germans themselves call it from its voice, *lerche*. Shall we then argue, that *i* and *e* are the same?

"The *Latins* have named the cuckow *cuculus*, with the letter *u*, while the Greeks, from the same sound, have called it κόκκυγα: Is the *o* therefore to be pronounced like the *u*; for the note of the cuckow has the sound of *u* more than of *o*? The sound is, *cuc-*

uc, not *cococ*, or as the innovators (the Νέοφυτοι) pronounce it, cöcöc.

"The sound of a *trumpet* is expressed by *taratantara*; although we can imagine in it the sound of other vowels more easily than that of *a* only.

"The sound of a lash or thong, is expressed in *Plautus* by the word *tax*. Others express it by *kliszsch, klatsch, schmitz, schmatz, patzsch, peitzch*, &c. Has *x* therefore the same sound with *tz*, or *tzch*? Or are these different vowels equivalent to each other? The same remark may be made of various other words of this kind"—

"*Schmidt* then adds, with some humour—"Nimis ergo infirmum fundamentum suæ pronunciationis posuere miseri illi *verveces*, qui vocem ovium substravere. Quâ tamen, si ita lubet, uti eos, imo et ovium more, tremulum τὸ η pronunciare facile patiemur."*

By this time, perhaps, this celebrated argument will appear to be less conclusive in respect to the sound of the *Beta*, than might at first view be supposed. The truth probably is, that the syllable βῆ was used in this instance, not because it perfectly represented the sound in question, but because (to Cratinus' ear at least) it only expressed it with more exactness, than any other syllable to be found in the Greek language. And why is it not just as probable, that so long ago as when *Cratinus* flourished, this writer should have contented himself with a word, which was only an *approximation* to the true sound, as that the grammarians and lexicographers down to the time of *Phavorinus* (only three hundred years ago, when we *know* that the β had the sound of *V*)

* Havercamp, Sylloge, tom. ii. p. 661.

should have transmitted this word from age to age, without ever intimating, that it was a poor imitation, because it began with a letter, which sounded like *V* and not like *B*? Yet it has been so transmitted to us; and *Phavorinus,* following *Eustathius* and the *Etymologicon Magnum,* makes no other remark than this—(after speaking of several other words which the ancients used to express various noises) Ὀι δε ἀυτόι (the ancients) *φάσιν ὁμόιως μιμητικῶς καὶ* Βῆ *οὐ μὴν* Βαὶ *μίμησιν προβάτων φωνῆς.* Κρατῖνος,

Ὁ δ' *ἠλίθιος ὥσπερ πρόβατον* Βὴ Βὴ *λέγων βαδίζει.**

Here, we find, that although *Phavorinus* notices the word so particularly, as to tell his readers, that the ancients wrote it *βὴ* and not *βὰι,* (which, in his time, we know were pronounced *vee* and *vay)* yet he says not a word implying, that it was an imperfect representation of the sound in consequence of its beginning with a *Beta.*

Another argument for the *Erasmic* pronunciation of the *Beta* is founded upon the practice of the Greeks in writing *Roman* names; in which case it is urged (and with truth) that they rendered the *B* by their *β*; as in *Fabius, Tiberius, Gabinius,* which they wrote Φάβιος, Τιβέριος, Γαβίνιος, etc.; and on the other hand, the *Romans* used their *B* for the Greek *β*, when they had occasion to write Greek names, as *Bacchus* for Βάκχος, etc. *Beza,* however, candidly admits, that this is by no means satisfactory; because the Greeks not only represented the Roman *B,* but the *V* also by *β*; of which he adduces some instances himself, as Βέῤῥης, Βαλέριος, for *Verres, Valerius,* etc.; and it is a well known fact, that in Roman names, which had a *V* in them, the

* Phavorin. 1186. v. Λιτάς.

Greek writers made use of the letter β and the diphthong ου, indifferently, to represent that letter. Hence *Virgil* was called sometimes Βεργίλιος and sometimes 'Ουεργίλιος; *Valerius* was either Βαλέριος or 'Ουαλέριος. Now, as the learned all agree, that this diphthong was sounded like the French *ou*, or the English *oo (which is also the pronunciation of the Modern Greeks)* it follows, that, whether the two *Roman* letters *B* and *V* sounded alike or not, the *Greek* β and the diphthong ου must have been alike ; and consequently, that the *Beta* must have represented the Roman *V* with as much exactness, as the diphthong ου did. And it is certainly a striking fact, that this diversity of orthography, in writing foreign names, has descended to the *Modern Greeks;* for when they write names having a *V* (or a *W)* in them, they sometimes use β and sometimes ου, as may be seen in the following instances, taken from *Meletius'* Geography;* some of which, however familiar to us in our own language, will hardly be recognized in a Greek dress :

V rendered by β and ου:

Βενετία		Venice
Βερσαΐλλες	or 'Ουερσαλία,	Versailles
Βερμοντ		Vermont
Βιργινία	or 'Ουιργινία	Virginia
Πεννσιλβανία	or Πεννσιλουανία,	Pennsylvania, etc.

* Μελετίου γεωγραφία παλαία καὶ νέα, etc. the second edition, in 4 vols. 8vo. printed at Venice in 1807.

W rendered by *β* or *ου*:

Βασιγγτὸν,	Washington
Βισκασσὲτ,	Wiscasset
Βιλμιγγτὸν,	Wilmington
Ὀυαλλία,	Wales
Ὀυΐλνα,	Wilna
Ὀυατερφὸρδ or Βατερφὸρδ,	Waterford, etc.

But the most valuable and interesting monuments of antiquity, relating to the subject now under consideration, are the *Greek Versions* of the *Roman Law*, and the *Greek Commentaries* upon it. In those Versions and Commentaries, we do not merely find a few scattered proper names of Romans, written in Greek, as is the case in the small number of Greek historians, that have come down to our times; but in every page we meet with *technical and other words* of the Roman Law, which, as they could not be well translated, were adopted, almost in their native *Latin* form, and only written in *Greek characters*. Now, although these Versions will not be esteemed of so high authority, as the writings of the Augustan age, yet, when we find in them a great weight of evidence, proving, that the pronunciation of Greek has remained unchanged from the age of *Justinian* to the present time, (a period of about *thirteen* centuries,) we shall not readily believe, that any material change could have taken place in the comparatively short period of the *five* preceding centuries; which would carry us back to the Augustan age. I shall cite only a few examples as to the letter *Beta*. In some parts of the *Code*, the Emperor *Valentinian* is called in Greek Βαλεντινιανὸς, while in others, his name is writ-

ten Ὀυαλεντινιανὸς.* The Emperor *Justinian's* title of *Vandalicus* is commonly written Βανδαλικὸς, as in tit. xvii. 3.; and in the same law, the Latin phrase *post Vandalica trophæa* is rendered by, *μετὰ τὸ κατὰ Βανδίλων τρώπαιον*; and the emperor's name is usually written *φλα* Βιος Ιουστινιανὸς. Of *technical* words, where the Latin *V* is rendered by the Greek *β*, we find innumerable instances, like the following—*βακάντια (vacantia*, sc. bona) *βεκτιγάλιοι, βινδικτα, βολουντας, ιντερ-βίβος, ιντερβάλλουμ, πραεβαρικάτωρ, πριβάτα, προ-βιρίλι, σακρα-βια, σεπούλκρι-βιολατι*, etc. I will add but one instance more of this kind; which contains, at the same time, an example of the use of the letter *B* for *V*, and a rule of the testamentary law of the Romans, to which a professional reader may trace a rule of our own law: It is to be found in the curious work of *Eustathius* Περὶ *χρονικῶν διαστημάτων ἀπὸ ῥοπῆς ἕως ρ ἐτῶν*: *De Temporalibus Intervallis à momento usque ad centum annos;* or, as we should say in technical language, *On Limitations, from one moment to an hundred years:* Εισω *λ' ἡμερῶν ὀφειλει ἄρχεσθαι ὁ κληρονόμος τοῦ* ΙΝΒΕΝΤΑΡΙΟΥ *μετὰ τὸ ἀνοιγῆναι τῆν διαθήκην*, etc. Intra dies triginta debet hæres *InVentarium* incipere postquam apertum fuerit testamentum, etc.†

The argument also, which is founded on the Greek method of writing *Hebrew* words, and which has been adduced in support of the *Erasmian* pronunciation of *Beta*, is, in truth, against it; for it will be found, as both *Martin* and *Schmidt* observe, that the Greeks used their *β* to represent not only the Hebrew ב (both *without the Dagesh* and with it) but also the Hebrew ו; as in דויד Δαβίδ, אַבְרָהָם Ἀβρααμ, etc. instances of which may be found in every page of the Septuagint.

* Cod. I. i. 3. and I. xii. † *Eustath. ap. Cujac.* tom. i. 566.

Γ.

The letter γ, when single, has two sounds in Modern Greek. Before α, ο, ω, ου, it has, what we call in English, the *hard* sound of *G*, as in *game*, *gone*, &c.; but before ε and ι it has the sound of the Italian *J*, or our *Y:* Thus (to take an example from *Velastus'* Treatise) γέρας is pronounced *yáras;* γίνομαι, *yeenomay.*

The former of these sounds is universally admitted by the learned to be the ancient one; but the latter has been much contested; and among the reasons for controverting it, *Metkerke* (copying from *Beza*, as usual) assigns this very extraordinary one—that we cannot give *two different sounds* to the same letter without acknowledging a degree of poverty in the Greek language, which is not credible! To which *Martin* very justly replies, that this reasoning is "*plane ridiculum*," and only betrays *Metkerke's* own "poverty of argument." *Martin* then proceeds to defend it upon the ground of usage; which, so far as my inquiries have gone, is the only ground upon which it can rest; and this, surely, (if I may use a professional phrase,) is sufficient to throw the burden of proof upon those who condemn the pronunciation as spurious. It may, however, be further observed, that this soft sound of the γ might once have been similar to that, which is sometimes given to the *G* in English, in the words *guide*, *disguise*, &c. as if written *gyide*, *disgyise;* from which it may have naturally changed to the simple sound of *y*, as we now find it. Indeed, in some combinations, it does take a sound which cannot be distinguished from this.

But the pronunciation, which was most controverted by some of the Erasmians, is that, which is given to this letter, when it precedes another γ, or κ, ξ, or χ; in which cases the *Modern Greeks* give it the sound of *n*, as we have always been accus-

tomed to do, and as is now the practice in Europe. This pronunciation, so different from the usual sound of the letter *G* in European languages, was received from the Greek exiles themselves; and as they could not have produced any other authority for it, than they did for the pronunciation of many other letters of the alphabet, that is, *their own invariable usage,* it seems surprising, that the learned were willing to tolerate this, any more than the other peculiarities of the *Modern Greek* pronunciation. It was, indeed, opposed with so much learning and ingenuity, by *Beza* and *Henry Stephens,* that great doubt has been entertained, whether it was genuine. But, as we now have evidence, which, it is not saying too much, to call conclusive, (as will presently appear,) it will be a useful lesson to us, who are but *foreigners* as to this question, to recur to the *theoretical* arguments, which those eminent men and their followers have urged against it. It will teach us to be cautious, in questions of this nature, how we condemn the universal and very ancient usage of a whole people, whenever it happens to be repugnant to our own habits or prejudices.

Beza, after some remarks on *Theodore Gaza* and the "grammarians," asks, "why cannot the double γ be pronounced by the *Greeks,* as well as by the *Latins* in their words *aggrego, agger,*" &c. and he then goes on, in a decided tone, to assert, that "neither the double γ is to be found among the Greeks, nor the γ written before κ or χ; and that what *Gaza* adds in his rule about the ξ is idle, because neither γ nor ν are to be found before ξ among the Greeks; but the grammarians have been deceived in this matter; for they have not considered, (as he remarks with ingenuity,) that the copyists of books, before the invention of printing, did

not write in large or *capital* letters, but in *small ones,* fashioned after the *ancient capitals,* but still with some slight differences; and thus, in transcribing, they would by lengthening and widening the ν before a γ, make it resemble the latter so much as to be mistaken for it."* He then informs the reader, that in a very old MS. of St. Paul's Epistles, which was written in *capitals,* he had seen the following words written with a ν instead of a γ: ΑΝΓΕΛΟΣ, ΑΝΚΥΡΑ, ΑΝΚΑΛΗ.

However ingenious this conjecture of *Beza* may appear, and however well supported it may seem to be, yet it is all overthrown by the evidence now in possession of the learned, to which I have just alluded; that is, the *Herculanean Manuscripts;* which, as Dr. Burney justly observes of one of them, are "undoubtedly the most curious publication, on the whole, which has appeared since the revival of letters."† I shall make no apology for introducing in this place a translation of the entire note of the learned editor on the pronunciation of the letter now under consideration. It is taken from the *second* volume of the Man-

* *Beza,* De germana pronunciatione Græc. Ling. ap. *Havercamp. Syllog.* tom. i. p. 314, 315.

† See *Rees' Cyclopædia,* art. Philodemi de Musica. Dr. Burney states, that no copies of this work had reached England till 1801, (though it had been then published several years,) when "Dr. *Cracherode* procured possession of two copies." It is honourable to our country, that we now have in this vicinity three copies, at least, of this interesting publication; one of which is in the Library of the University at Cambridge, and another in that valuable repository of literature, the *Boston Athenæum.* This institution, indeed, is the only one, I believe, that possesses the *second* volume of these MSS. containing part of the works of *Epicurus* and some fragments of a Latin poem. This volume was not printed till 1809.

uscripts, which contains a part of *Epicurus*. The note is to be found at p. 23, where the word συνκρισεις occurs, written incorrectly with a ν instead of γ; upon which, the editor says to his reader—"It will be observed, that the original manuscript has here συνκρισεις, with N instead of Γ; which is to be ascribed only to the inattention of the copyist. For you must take care, that you do not adopt the opinion of *Stephens*, *Beza*, and others; (cited by Jo. Simon, in his Introductio Grammatico-Critica, sect. 2.) who, because they found in a manuscript written in *capitals* the words ανγελος, ανκυρα, written as συνκρισεις is in this place, supposed, that the grammarians, when they directed γαμμα to be written for νυ before the palatal letters, were deceived by the lengthened figure of the ν, which looked like a γ. Now in these *Papyri*, which are written in *capitals*, γαμμα is constantly written before the palatal letters, (although sometimes the transcriber erroneously departs from this orthography,) as may be seen in this very volume, (or *roll*) where, at col. ix, v. 12, you find εγχειρουσιν correctly written. In *Philodemus de Musica*, which we have published, you will see, that this orthography is constantly observed. Thus, Col. xvii, v. 31, τυγχανειν; ib. v. 44. συγγενη. Col. xxiv, v. 7, συγγενως. Col. xxvii, v. 18, αγχινοιας. Col. xxxiii, v. 22, αναγκαιως. Col. xxxviii, v. 32, εγκεχειρηκασι; but in the same place, the transcriber, nodding, (*ut in longo opere*, &c.) wrote at v. 38, συΝκατακοσμησιν, as I have there observed. This rule of orthography is constantly observed in the other *rolls*, which we have by us; and so closely is it followed, that sometimes, in the case of *two succeeding words*, when the last begins with γ, and the first should end with ν (as in μεν γαρ)

such first word is written with a γ in this manner, ΜΕΓ ΓΑΡ. Now this, unless I am mistaken, is a manifest proof that the γαμμα had retained the sound of the νυ, although it might be pronounced somewhat more softly; as we at this day pronounce the words *angelus, anchora;* in doing which the tongue does not rise quite up to the roof of the mouth. If such were not the case, the letter N would not be so easily substituted for the Γ by the transcribers."

Δ.

The letter δ has the sound, which *Walker* calls in English the *flat* sound of *th;* as in our word *then,* which may be expressed with great exactness, as to sound, by the negative particle δὲν of the Modern Greeks, a corruption of the ancient word ὀυδὲν. This approaches so near to the common sound of the letter *D* in the modern languages, that it does not appear to have given occasion to much controversy. It must, doubtless, be defended, upon the ground of *usage;* which, one would think, should be as decisive in the case of this, as of its kindred letter, *theta,* which has been acquiesced in by the learned of all countries.

E.

The sound of this letter, which is that of *e* in the European languages generally, is the same, substantially, with our *e* in the word *there.* This pronunciation of ε is universally considered to be the same with that of the *ancient* Greeks.

Z.

The pronunciation of the letter ζ is also, in practice, undisputed: The learned of all nations agree in giving it the sound, which *z* has in English; which is also the pronunciation of the Modern Greeks.

H.

It has been the fate of this letter, as writers have remarked, to be the subject of as much controversy as any in the whole alphabet. *Erasmus* and his followers contended, that the *ancients* pronounced it like what they called long *E* in Latin; by which they meant a sound like *a* in our word *fate*. The *Modern Greeks* pronounce it like our *ee;* which is the sound given to it by the English, and which we have always been accustomed to give it. As far as respects ourselves, therefore, we have no dispute with the *Modern Greeks* about this letter. But the writers on the continent of Europe have generally considered that pronunciation as erroneous; it will, therefore, be necessary, to notice briefly the grounds, upon which the two modes are defended.

That this letter at one period had a sound differing in some respects from that, which it now has in Greece, must be inferred from the description given of it by Dionysius of Halicarnassus, which is different from his description of the sound of *Iota;* and this latter indisputably had the sound of long *e* (or *ee)* in our language. In the Herculanean manuscripts too, the η is sometimes used by the copyist, through mistake, instead of *Epsilon.* But there is also a great mass of evidence tending to show, that about the commencement of the Christian era or not long afterwards, the η and ι were both pronounced alike; and, if we can

ascertain the pronunciation of the language as far back as that period, it will be sufficiently near the classic ages of Greece, to satisfy the most fastidious ear of *foreigners*, as we are in respect to the language. The arguments on both sides of the question respecting the η, are very minutely stated (from various authors but not without remarks of his own) by *Velastus*, a Greek monk of the island of *Chios*, in the *Dissertation* to which I have before referred, and in which upwards of thirty quarto pages are devoted to this letter alone.* I shall here only give a very general view of the reasoning on the subject; and, in doing this, it will be necessary for the present to assume as true, that the diphthong *ει had the same sound with the ι*; which, by the aid of the *Herculanean Manuscripts*, in addition to the ancient monuments heretofore discovered, may now be proved beyond a doubt to have been the case.

In prosecuting this inquiry, we are enabled to go back at once to the twelfth century by means of the writings of the learned and venerable *Eustathius*; and he, it should be recollected, expressly informs his readers, that his *Commentary on Homer* consists chiefly of *selections from the works of others*, whom even in that age he styles "*the ancients*." Among those writers, (upwards of three hundred and fifty in number, according to the catalogue in Fabricius,†) we do, indeed, find the names of philosophers and critics and grammarians from the very earliest periods of Grecian literature. Now *Eustathius*, in the course of his Commentary, gives several instances of what he calls παρήχησις, or words, which

* Thomæ Stanislai Velasti, societatis Jesu, *Dissertatio de Literarum Græcarum Pronunciatione*, Romæ, 1751.

† Fabric. Bib. Græc. tom. 1. p. 506.

are alike *in sound* but different in *signification;* and as examples he gives these lines of Homer, among others, relating to the letter η:

Τὸν καὶ ὑπέδδΕΙσαν μάκαρες θεοὶ οὐδέ τ' ἔδΗσαν.

Iliad. A. 406.

——————— χόλος δέ μιν ἄγριος ΗΡΕΙ·
ΗΡΗ δ' οὐκ ἔχαδε στῆθος χόλον.

Iliad. Δ. 23, 24.

ΙΡΙ θεὰ, τίς γάρ σε θεῶν ἐμοὶ ἄγγελον ἧκε;
ΗΡΗ με προέηκε.

Iliad. Σ. 182, 184.

Upon which last example he particularly remarks, that the Poet has here placed two words near each other, which form the most perfect kind of *parechesis;* which is, when the words are exactly similar *in sound,* but dissimilar in *signification and orthography*—Ἐγγὺς ἀλλήλων τίθησι, κατὰ τοιαύτην παρήχησιν, παντελῶς μὲν ἠχοῦσαν ταυτὸν, ἀνομοιότητα δὲ ἔχουσαν κατά τε τὴν ἔννοιαν, καὶ κατὰ τὴν γραφήν.*

In another instance (*Iliad.* O. 143, cited by *Velastus*) he uses even more emphatic language; for after citing these lines,

Ἥρη δ' Ἀπόλλωνα καλέσσατο δώματος ἐκτὸς
Ἶριν θ' ἥ τε θεοῖσι μετάγγελος ἀθανάτοισι,

he remarks, that the poet describes *Iris* paraphrastically, as the messenger of the gods, lest the perfect similarity of sound in ἥρης and ἴρις should mislead one, and *Juno* should be supposed to have been called for by *Juno* herself.

* *Eustath.* p. 240. edit. Florent. 1730.

But it is needless to multiply examples of this kind; and I shall merely refer to the two lists of words at the end of *Scapula's* and some other Lexicons; one of which (by *John Philoponus*, as Henry Stephens affirms) will carry us back to the seventh century, and the other, by *Ammonius*, to the fourth century; from which last work, we may proceed still farther back, by means of a writer there cited, by the name of *Didymus;* who thinks it necessary to point out the difference in *signification* between the two words λητουργεῖν and λιτουργεῖν; which, if they had been so unlike *in sound*, as the Erasmian pronunciation of η would make them, would not have been classed with the words in this Collection.

The argument founded on *translations* of Roman names into Greek is also applied in the case of the η, as well as of the other letters; and it is observed, that *Dionysius of Halicarnassus*, and other Greek writers, rendered the Roman *i* by the η of their own language. But on the other hand, the *Roman* writers frequently rendered the Greek η by their own *e*. Again, it may be replied, that (as *Gellius* observes) the ancient Romans used *e* and *i* indifferently; and Quintilian informs us of the same fact; and, by way of example, he remarks, that the ear cannot plainly distinguish whether the Latin word *Here* has the sound of *I* or of *E;* and that in the works of many authors he found *sibe* and *quase* for *sibi* and *quasi.**

But the strongest argument from *translations* is derived from the *Oriental* Languages, because of their antiquity and permanency. *Velastus* alludes to this, but contents himself with referring the

Quintil. Instit. lib. 1. capp. 4 and 7.

reader to *Wetstein's* Dissertation. It is, however, urged with much force against the Erasmians, by *Martin* and by *Schmidt.* The former, in his reply to *Metkerke,* (who had incautiously adduced it as being favourable to his own cause,) thus presses his adversary: "What shall I say on this point, *Metkerke;* or rather what shall I not say? In truth, when you appeal to the *Hebrews,* you betray your utter ignorance—*Hebræos prorsus non intelligis*—nor, as it appears, have you ever read a passage in their language. For what in the Greek is rendered by η, is in the Hebrew *i* long [that is *ee*] and therefore in *Greek* it must be pronounced in the same manner." *Martin* then examines the Hebrew words referred to by *Metkerke.* *Schmidt* remarks, that in a multitude of Greek words which are retained in the *Syriac* Version of the New Testament, the Greek η is *always* rendered by *Hirik* and *never* by ֵ or by ֶ — thus,

כִּאפָּא from *κηφᾶ*, Matt. xvi. 18.

פָּרַקְלִיטָא from *παράκλητος*, John xiv. 16.

דִּיָתִיקִא from *διαθήκη*, Matt. xxvi. 28, Luke i. 72.

קוֹרְנִילִיוֹס from *κορνήλιος*, Acts x. 1.

פֶּנְטִיקוֹסְטִי from *πεντηκοστὴ*, Acts ii. 1.

זִאטְמַא from *ζήτημα*, Acts xviii. 15.

with some other examples, which it is needless to particularize in this place.

It is only necessary to notice one other argument in this case; which is the syllable Βῆ used by *Cratinus* (as before observed) to express the cry of a sheep. In addition to the remarks made under the letter *Beta,* I need only observe, (as *Velastus* does, after *Fabricius,*) that there were two writers of the name of *Cra-*

tinus, both of whom lived long before the time of Plato, Thucydides and Pericles; a period, to which no one will attempt to trace the pronunciation of the Greek language, and at which time the letter η might possibly have had the full sound of our long *a* throughout all Greece. But it is worthy of remark, that the word Βῆ is spoken of by *Suidas* and the author of the *Etymologicon Magnum* as an *Attic* word—BH, το μιμητικὸν τῆς τῶν προβάτων φωνῆς, ὀυχὶ BAI, λέγεται Αττικῶς;* an expression, from which we must infer, that the word in question was peculiar to the people of Attica; and that the people of other parts of Greece would have used another word, to express the same sound.

Θ.

The *Modern Greeks* pronounce the letter ϑ just as we do *th* in our words *thank, think,* &c. and this has always been admitted by the learned, from the days of Erasmus to our own times, to be the ancient pronunciation. Yet it is difficult to perceive, why the modern sound of this letter should not have been contested, as well as that of several others in the alphabet.

I.

The sound of the letter ι is also universally agreed to have been the same anciently, as at the present day; that is, like long *e* (or *ee*) in English; and so it is always pronounced on the continent of Europe.

* Etymol. Magn. p. 196. *edit. Sylburg.*

K.

The pronunciation of the letter κ is also admitted to have been that of *k* in the languages of the present day; as the Modern Greeks always pronounce it.

Λ.

The letter λ is supposed to have had anciently the common sound of *L* in the European languages. The Modern Greeks also give it the same sound before the vowels α, ε, ο, ω; but before ι and υ, it seems, they give it the liquid sound of *gl* in Italian; as I have remarked in the Table of the Alphabet, at p. 237. Whether this distinction was observed anciently does not appear.

M.

The pronunciation of the letter μ is supposed to have remained unchanged to the present day. It has the common sound of *M* in all the modern languages.

N.

The ν in Modern Greek, before α, ε, ο, ω, has the common sound of *n* in the European languages; but before η, ι, υ, (as I am informed by the Greeks I have mentioned,) it has the sound of *gn* in the word *bagnio;* as I have before observed, in the *Table of the Alphabet.* European scholars use only the first of these sounds.

Another modification of the sound of this letter, among the Modern Greeks, takes place when it is followed by the consonants β, μ, π; in which case it slides into the sound of *m.*

This modification of ν, though so natural a consequence of the combination of these letters, was utterly proscribed by the learned of Europe. *Mekerchus* asserts—"Now, that ν ought always to be pronounced like *n*, and that before β, μ, π, its sound should not be changed into *m*, is sufficiently proved by this; that it has neither the authority of the ancients, nor euphony, to recommend it, and that all the letters should sound as they are written; and the learned pronunciation is elegant and not difficult." He then adds, that he supposes "certain sciolists, who had more knowledge of *Latin* than of *Greek*, must have made this change, in consequence of their observing that the *Latin* prepositions *an*, *in*, and *con*, before *b*, *m*, *p*, in compound words, were changed into *am*, *im*, and *com*."*

Henry Stephens also (following *Mekerchus*) peremptorily decides, that this modification of the ν is the work of *sciolists*—"illud decretum (says he) quorundam sciolorum." He then argues, that this pronunciation occasions ambiguities and deformity in the language; and that "these sounds are like great monsters, which every man ought to attack with the club of Hercules;" and therefore we ought to reject this pronunciation. But the only reason he gives for his opinion is a remark of *Quintilian*, who says, that in *Greek* no word ends in *m*. The remark of *Quintilian*, however, does by no means warrant the inference thus drawn from it. Now, that the ν anciently took the sound of μ, when it was followed by any one of the letters β, μ, or π, it may be hazardous to affirm; but it is certainly a little remarkable, that, contrary to the opinion of those learned men, we find, in the *Herculanean Manuscripts*, evidence of its having that sound when it was fol-

* *Mekerchi Comment.* p. 162.

lowed by the β. The learned editor of the manuscript of *Philodemus* states, that ν is *frequently* substituted for μ in that work; and he gives the following, as one instance of such false orthography; which must have been occasioned by the similarity of sound in that combination: "*Sæpe* enim librarius noster ν pro μ scribit; ut hac ipsa columna videre est, v. 14, ubi απολανϐανουσιν pro απολαμϐανουσιν, legitur; etsi col. 1. recte scripserat αντιλαμϐανονται et παραλαμϐανουσθαι: quod ejus sive imperitiæ sive oscitantiæ tribuendum."* Here, then, we have another instance, where the usage of the *Modern Greeks,* contrary to the theories of ingenious and learned Europeans, is confirmed.

Ξ.

The ξ always has the sound of *ks,* as well at the *beginning,* as in the other parts of a word; never, that of *gs* or *gz,* and much less, that of simple *z,* which we are accustomed to give it at the beginning of words. The sound of *ks* perfectly agrees with the description given of this letter by Dionysius of Halicarnassus, who says, it is compounded of κ and ς, but does not intimate that it has any thing of the sound of γ in it.

O.

The general pronunciation of ο is as nearly like that of *o* in the word *nor,* as any sound which we have in English; but it may be more exactly described, as a sound between that and the sound of *o* in the word *no.* The learned make no question as to the antiquity of this pronunciation.

* *Philodem.* col. ii. l. 27.

Π.

The letter π, it is universally agreed, had anciently the sound which it now generally has in Greece; that is, of the letter *p* in the modern languages. When, however, it is preceded by a *flat* consonant, (as *Walker* denominates that class of letters,) it is very naturally modified by it. Thus, if preceded by μ, it takes the sound of β; as, ἄμπελος is pronounced *ámbelos*. Such modifications of the general sounds of letters are common in every language. In the present instance, we see, in the *Greek* language the letter π being preceded by a *flat* consonant, takes the sound of β; in *Latin*, on the other hand, we have a well known instance from *Quintilian*, where the letter *b*, when followed by a *sharp* consonant, *t*, slides into the sound of *p*: "—— ut cum dico *obtinuit* (says he) secundam enim *b* literam ratio poscit, aures magis audiunt *p*."* Whether the ancient Greeks thus varied the sound of the π, it is impossible to determine with certainty. But it will, most assuredly, be safer to follow the present usage of the *natives* of Greece, than to rely upon the theoretical opinions of *Mekerchus* and other *foreigners*, who assert without proof, that such a modification of the β is "ridiculous."†

Ρ.

The pronunciation of the ϱ is undisputed. It is agreed, that it has always had the sound which *r* has in modern languages.

* Quintil. Instit. lib. i. c. 7. † *Mekerch*, p. 162.

Σ.

The sound of the letter σ is universally agreed to be, that of *s* in the languages of our own times. We sometimes give it the sound of *z* in certain combinations; and it is, in fact, occasionally modified by other letters; thus, the expression υἱὸς μου would sound, to our ears, like ὑιὸζμου, in consequence of the *flat* consonant after the σ. But, generally speaking, we should take care to give this letter the pure sibilant sound of *s*.

T.

The general pronunciation of the letter τ is agreed to have been anciently the same that it now is in Greece; that of the modern *T*. But the Greeks of the present day, when this letter is preceded by ν, give it the sound of *d*; thus, παντελῶς is pronounced *pándelos*. This pronunciation was violently opposed in the Erasmian controversy; but principally on the ground, that it was inconsistent, that the same letter should have more than one pronunciation; and yet all the writers in that controversy (who were Frenchmen, Dutchmen and Englishmen) must have observed the like *inconsistencies* in their own languages. In this and other cases, where we have no evidence in the works of ancient writers, the *general usage* of Modern Greece ought to have great weight.*

* It should have been remarked under the letter κ, that the same modification takes place in that letter, when preceded by a *flat* consonant (γ) as we find in the other two mutes, π and τ; thus, εγκέφαλος is pronounced as if written εγγέφαλος.

Υ.

The Modern Greeks pronounce υ like their ι, or like our *ee*. Strange as this may at first seem to us, there can be little doubt, as will presently appear, that this is extremely near its original sound; and probably, is exactly the sound it had as long ago as the *first century*. *Henry Stephens* and other French writers (and indeed most writers of other nations) have no doubt, that it was originally pronounced like the French *u;* and the description given by *Dionysius of Halicarnassus* of its pronunciation in his time, corresponds in a very striking manner, with that sound in the French language. After observing, that in pronouncing ω, the mouth is rounded and the lips drawn towards each other, he adds—"Εϛι δὲ ἧττον τούτου τὸ υ· περὶ γὰρ αὐτὰ τὰ χέιλη συϛολῆς γενομένης ἀξιολόγου, πνίγεται, καὶ ϛενὸς εκπίπτει ὁ ἦχος—The υ is inferior to this; for a remarkable contraction of the lips is made, and a slender stifled sound is uttered."* Now the *u* in French borders so nearly upon our *ee*, that in learning the language, students, during their first awkward efforts to attain this difficult sound, generally pronounce it like *ee*. That the υ, however, shortly after the time of *Dionysius of Halicarnassus*, had the simple sound of *Iota*, is now rendered in the highest degree probable, by what we find in the *Herculanean Manuscripts;* where it is sometimes erroneously used by the copyist for the letter ι. The learned editor of *Philodemus* makes the following remark upon it: "Sic. v. 17, [col. vii.] pro δΙδαγμα habes δΥδαγμα, et v. 19, pro ακολασιαν, αχολασιαν, quæ omnia bonus

* Dions. Hal. De Structura Orat. sect. 14. p. 96. edit. Upton.

Conrector fidenti oculo est prætergressus. Nonne autem hinc horum elementorum valde adfinem sonum apud veteres arguere licet?"* Thus it appears, that the modern pronunciation of this letter may be traced back, with great probability, to the commencement of the Christian era; a period, which may properly enough be considered as classic. It should also be noticed, that in the present instance, the υ is thus substituted for ι in an *accented* syllable; which, if the *ancient Greeks* regulated their pronunciation by the *accents* as their descendants do, adds greatly to the force of the argument in this case; for an *accented* syllable would not be likely to be written with letters, which had not a very close affinity to each other in sound; whereas *un-accented* syllables, on the contrary, might be spelled with letters, which would not, of necessity, very closely resemble each other. This circumstance, by the way, will, as I am strongly inclined to think, explain many of the seeming contradictions in the arguments, which are founded upon the instances of false orthography in ancient manuscripts.

Φ.

The letter φ, it is agreed, had anciently the same sound which is given to it by the Modern Greeks; that is, the sound of *F*. But, from the remark made by *Cicero* upon a Greek that could not pronounce *Fundanius*, but said *Fhundanius*, it was doubtless uttered more forcibly, or with a stronger compression of the lips, than the Latin letter.†

* Philodem. p. 36.

† See Quintil. lib. i. c.

X.

The learned all agree, that the letter χ was pronounced by the ancient Greeks with a strong aspiration; like the *ch* in German, or, much as the letters *gh* final are pronounced by the Irish and Scotch. The *Modern Greeks* give it the same sound. That it had some resemblance to the κ, appears from its being sometimes substituted for it in writing; as in the instance above cited from the *Herculanean Manuscripts*, under the letter Υ, where αΧολασιαν is written for ἀΚολασιαν.

Ψ.

The pronunciation of the letter ψ is undisputed. It is admitted by all, that it had the sound of *ps;* though occasionally modified by the other letters, so as to sound sometimes like *bs.*

Ω.

The Modern Greeks pronounce the ω just as they do the ο; and it seems to be undeniable, that anciently they differed only in *quantity* but not in *sound.* Before the discovery of the *Herculanean papyri,* it had been observed that they were frequently interchanged by transcribers; and we now find the same thing in those manuscripts. The editor of *Philodemus* has this remark upon it, col. xvii, v. 14; where he says we should read (to use his language) "pro αμεινον fortasse αμεινων, v. 16, pro των μετρων refingendum τον μετρον."*

A few remarks upon the sounds of the *diphthongs* will conclude what I have to offer at present upon this subject; but before ex-

* *Philodem.* in not. p. 78.

amining each one by itself, it may be proper to notice an objection, which is applicable to the modern pronunciation of them all. *Erasmus* contended, that in all of them, the sound of both the component letters should be heard. Otherwise (says he) "why are they called proper diphthongs, unless the syllable gives the sound of the two vowels?"* *Beza*, and after him, *Metkerke*, and various other writers, hold the same language; and think, that, as the very name of *diphthong* means a combination of two *sounds*, therefore they must have been pronounced in that manner, and not according to the practice of the Modern Greeks, with one simple sound only; for if this were the case, they argue, these combinations of letters would not have been called *diphthongs*, but *digraphs*. At this day it seems truly surprizing, that the writers in the controversy (who were Dutchmen, Frenchmen and Englishmen) should have overlooked the circumstance, that the same abuse of the term *diphthong* was to be found in their own, as well as in other languages. To apply their rule, therefore, those foreigners might argue, in respect to the English language, that there are certain combinations of vowels in it, which Englishmen call *diphthongs;* and as they are called *diphthongs*, and not *digraphs*, they must be uttered in such a manner, that the two sounds shall be heard! The mere application of the reasoning to our own language, shows its fallacy.

AI.

This diphthong is pronounced by the Modern Greeks like ε, or our *a* in *fate*. This pronunciation may be traced back, by means of the *Greek* writers, with perfect certainty to the twelfth

* Erasm. Dialog. p. 89.

century. ***Eustathius*** (as quoted by the writers in the controversy) after citing the following line from ***Homer***,

Αλλὰ πίθεσθε δὲ ὔμμες, ἐπεὶ πέιθεσθαι ἄμεινον,

remarks, that "πίθεσθε and πέιθεσθαι though they differ in their *letters* are exactly alike in sound;" and the same is the case, as he says, in this passage—Ὀφθήσῃ ΚΕΝΟΣ ἐναντίον μου, ἀλλ' ἄλλον τρόπον ΚΑΙΝΟΣ; "for here κενὸς and καινὸς have the same sound." Several other passages might be adduced from ***Greek*** writers to the same effect, though not so decisive as these. I do not find any, however, which carry us back to the first century; nor, on the contrary, do we find any remarks of these writers, which give the least intimation, *that any change had taken place* in the pronunciation of their language.

In the case of this diphthong, however, as in that of the letter η, we have evidence of this pronunciation of sufficiently high antiquity, in the ***Oriental*** languages. ***Schmidt*** observes, that in the ***Syriac*** Version of the New Testament, not only the Greek ε, but the diphthong αι, in those Greek words which are retained in the version, are expressed both by *tsere* and *segol;* as, κεφάλαιον, קֵפָלֵון; καισαρέια קֵסָרֵיא; εἰς πραιτώριον, לִפְּרֵטוּרִין, &c.*

ΑΥ.

The Modern Greeks pronounce this diphthong sometimes *af* and sometimes *av*, as observed in the Table of the alphabet. The argument of greatest antiquity is founded on a remark of Cicero, in his treatise ***De Divinatione;*** where he says, that when ***Marcus Crassus*** was embarking his army at Brundusium, some person

* *Schmidt*, De pronun. Græc. p. 638.

who was there selling figs brought from *Caunus,* cried, *Cauneas* [i. e. either Καυνείας, the Greek name or *Cave ne eas*] which was considered as an omen against his proceeding. "Hence (says *Erasmus Schmidt)* it is apparent that the Greek diphthong αυ very nearly corresponded to the Latin *av* as pronounced in the word *Cave.*" In addition to this, *Schmidt* again resorts to the *Syriac* Vĕrsion; where, as he says, the υ in αυ and ευ is rendered by ו, so as to sound like *V:* פּוֹלוֹס from Παῦλος; קלודיוס from Κλαύδιος, etc.

The most important argument *against* this pronunciation of αυ, is founded upon the well known passage of *Aristophanes,* where the barking of a dog is expressed by αὖ, αὖ; from which it is inferred, that this syllable must have been pronounced like *ow* in our word *how;* it being taken for granted, that *Aristophanes* used a word, which expressed the barking of a dog with exactness. But he might have used a word which was merely an *approximation* to the sound; and this will appear to have been the case. In addition to the observations under the letter *Beta* (p. 250) upon the uncertainty of arguments derived from *animal sounds,* I will only make one or two remarks applicable to this particular word. It is evident, from what has been already observed, that the letter υ must have been pronounced either like the French *u,* or like *ee:* This syllable then, if not pronounced *av,* must have sounded like our word *aye;* which no one will think quite so near the barking of a dog, as the present pronunciation, *av, av. Aristophanes,* then, must have adopted this word as an *approximation* to the sound in question.

EI.

The arguments in support of the Modern Greek pronunciation of this diphthong appear to be unanswerable. Indeed some of the writers on the *Erasmian* side concede the point. Without repeating the remarks of *Eustathius* and other writers, who may be thought not sufficiently *ancient*, I will only add to the observations made under some of the preceding letters, the following, from the *second* volume of the *Herculanean MSS.* which, at the same time, contains an important remark respecting the *accentuation* of words. After noticing the word εμποδειας, written with ει instead of ι, the editor says—"Quod autem pro simplici *iota* descriptum habeas ει, id somnolento calligrapho tribuas, qui sæpe non secus ac alii horum voluminum exscriptores, ut jamdudum observavimus, hujusmodi litterarum εναλλαγην facit. Et ne longius abscedas, mox hac ipsa columna v. 14, ἀοριστείας pro ἀοριστίας descriptum invenies. Id autem argumento nobis esse debet, non modo diphthongum ει affinem sono fuisse τω ι, sed etiam hujusmodi voces penultima longa solitas fuisse efferri."*

In the ancient *Greek Inscriptions* published by Dr. Clarke in his *Account of the Greek Marbles*, we also find evidence of the same kind respecting the ει: Thus, p. 5. ΤΕΙΜΟΘΕΟΣ ΔΑΣΕΙΟΣ ΧΑΙΡΕ ΤΕΙΜΟΘΕΟΣ, etc. Again, at p. 44. Η ΒΟΥΛΗ ΚΑΙ Ο ΔΗΜΟΣ ΕΤΕΙΜΗΣΑΝ ΤΙΤΟΝ, etc.

* *Epicur.* lib. xi. col. vi. p. 50.

ΕΥ.

There does not appear to be any direct evidence in the *Greek* writers of very ancient date, proving the sound of this diphthong to have been *ev* or *ef*, as the Modern Greeks pronounce it. If, however, there is reason to believe that αυ was pronounced *av* or *af*, the argument from analogy will apply with much force. But though we find nothing decisive in the *Greek* writers, yet we have evidence in this case also from the *Oriental* languages; for, according to *Erasmus Schmidt*, in the *Syriac Version*, ευ is rendered by ו, of which he gives the following instances:

אֻוטִיכוּס from Ἔυτυχος, Acts xx. 9.

אֶוְהָדִיָא from Ἐυοδία, Philip. iv. 2.

OI.

The diphthong οι is pronounced by the Modern Greeks exactly like *oe* in some English words derived from the Greek, or like *ee*. The antiquity of this pronunciation has been much contested. Most of the writers in the Erasmian controversy seem to have been of opinion, that the Greeks pronounced it just as *oi* is pronounced in the *French* language. The principal reason for this opinion was, the general one mentioned above; that a *diphthong* must have two sounds; an hypothesis, which is falsified by what every one of those writers must have found in his own language. That this diphthong has for many centuries had the sound of our *ee*, is proved by the same kind of evidence as above adduced in the case of some of the other diphthongs; that is, the mistakes of the transcribers of manuscripts; for they constantly substitute the

οι for η and ι. *Velastus* cites a striking remark on this subject of as old a date as the beginning of the fourth century. "Who (says he) has not heard of the complaints of *St. Jerom, Augustine,* and *Eucherius,* in respect to the word *Cenomia;* which, as it was written by the *Greeks,* sometimes κηνομυῖα, sometimes κυνομυῖα, and at other times κοινομία, in consequence of the identity of sound in all these words, occasioned infinite trouble to the interpreters of holy writ."* But the most ancient, and I think the most decisive, testimony in support of the modern pronunciation of this diphthong is, the passage, cited in the controversy, from *Thucydides.* This author, in his unrivalled description of the *Plague of Athens,* informs us, that during that calamity, the following verse, (which aged people said had been sung of old,) was, among other things, brought up to recollection:

Ἥξει Δωριακὸς πόλεμος καὶ ΛΟΙΜΟΣ ἅμ' αὐτῷ.

Upon which he remarks—"that a dispute arose among people, whether the oracle meant λοιμὸς, *a pestilence,* or λιμὸς, *a famine.* Their present sufferings (he adds) made them suppose the former was the word; for they adapted the oracle to the calamity of the times. But I am of opinion, that in case of another Doric war, if *a famine* should take place, they will be equally ready to apply the verse to that event." Now, if the two words in question were not pronounced alike, there could have been no room for this ambiguity; and to all the objections of those, who reason upon this verse, as if it had been in *writing,* it is a sufficient answer, that the oracles were delivered *orally.*†

* Velusti Dissertat. p. 80.

† This pronunciation of οι, it need hardly be observed, will destroy all the supposed force and beauty of our lofty πολυφλοίσβοιο θαλάσσης; which we apply

ΟΥ.

It is generally admitted by the learned, that the *ancient* Greeks pronounced the diphthong *ου* as their descendants do; that is, like *ou* in our word *you*, or like *oo.*

ΗΥ.

This is sounded by the Modern Greeks like *eev.* I have not found any particular remarks upon this diphthong; but the general reasoning in respect to the *αυ* and *ευ* will, in a degree, be applicable to it.

ΥΙ.

The sound of this diphthong is scarcely to be distinguished, except in length, from either of its two component letters taken alone. This pronunciation must undoubtedly be defended upon the ground of *usage;* I am not aware of any direct evidence relative to it in the Greek writers.

to the roaring of the *ocean.* But the following remark (from an intelligent writer before cited) will, at least, make us doubt of the justness of that application: "I must here add, that these men [some modern Greeks] confirmed an observation of our late revered and lamented President, that we are much mistaken in our idea of the supposed lofty sound of *πολυφλοίσβοιο θαλάσσης*; that the Borderers on the coast of the Archipelago take their ideas from the gentle laving of the shore by a summer wave, and not from the roaring of a winter ocean; and they accordingly pronounced it *Polyphlisveo thalasses.*"* The Greeks, I have conversed with, pronounce it in the same manner, and accenting the antepenultimate of the first word, and the penultimate of the second.

* Observations on the Greek Accents, by Arthur Browne, Esq. in the *Transactions of the Royal Irish Academy*, vol. vii. p. 370.

ΩΥ.

This diphthong rarely occurs; it is pronounced *oav* or *oaf* according to the consonant that follows it.

The improper diphthongs ᾳ, ῃ, ῳ require no particular remark; as the Modern Greeks, like ourselves, pronounce them just as the simple letters are pronounced without the subscribed *Iota*.

In addition to these particular observations on the letters, I cannot but call the attention of the members of the Academy to a few facts, which well deserve the consideration of scholars. Of these, a very important one is the *universality* of the pronunciation of the Modern Greeks; which is found to be substantially the same in the islands and other parts of Greece, quite remote from each other and having little or no connexion by means of commerce or otherwise. Another remarkable circumstance is, the use of *ancient Greek* in their Church-service; which has been continued from the first propagation of Christianity to the present day. Now the just pronunciation of the language of their Church-service has ever been scrupulously attended to; and the present mode has been handed down with extreme care from the earliest periods. The *nation* itself, also, remains to this time a distinct race of people; and it should be recollected, that the oppression of their Turkish conquerors has only served to keep them the more embodied, and the less liable to the effects of a necessary intercourse with each other.

How cautious then ought we, as foreigners, to be in condemning the invariable usage of a people thus circumstanced, in such a question as the pronunciation of their language. We perceive that the most eminent scholars have entertained opinions respect-

ing it, which later discoveries have proved to be unfounded. At one period, for example, it was contended by the learned of Europe, that the γ before γ, κ, &c. was not to be pronounced like ν; that ει was not to be sounded like simple ι, &c. as the Modern Greeks pronounce them. These opinions now appear to have been erroneous, and the usage of the *Modern*, is found to be conformable to that of the *ancient* Greeks. The learned also once thought, that the ancient Greeks used only *capital* letters, and that the *small letters*, now used, were the invention of the lower ages; but an inscription found in Herculaneum in these very characters has obliged them to abandon that opinion. They believed too, and with much ingenuity had almost proved, that the Greek *Accents* were of comparatively modern origin; but here again, unfortunately, the same Herculanean Inscription confuted their theories. In almost every instance, in short, where the opinions of the learned have been at variance with the usage of the *Modern Greeks*, whenever any evidence has been discovered relating to the point in controversy, the theories of the former have proved to be unfounded, and the usage of the latter confirmed.

I have thought it might be interesting, to some persons, to subjoin to this communication the following letter in *Modern Greek*, written by Mr. *Ciclitira*, of which a *fac-simile* is annexed. Those persons, who have not paid much attention to the language of Modern Greece, will, I am sure, be surprized at the resemblance of the words, and not less surprized to see the *accents, breathings*, &c. used so much in conformity with the rules in our grammars of *ancient* Greek. And on the subject of the *accents* (which I

shall consider in a future paper) I cannot avoid submitting one fact to the consideration of scholars—that the Modern Greeks always pronounce according to the accents; and, in *speaking*, they place the accent (or stress of the voice) exactly where the rules of prosody require us to place the *written* accent. For example: The word ἄνθρωπος, in the nominative case, they pronounce *ánthropos*, following the *accent*, and disregarding the *quantity* of the long vowel in the penultimate; but in the *genitive*, where the rule of prosody requires us to accent the penultimate because the final syllable is long, they place the accent (or stress of the voice) on the penultimate, also; and ἀνθρώπου is then pronounced *anthropoo*. This is noticed in the *Dissertation of Arthur Browne Esq.* before cited; and I have myself constantly found it to be the case both with Mr. Cicilitira and the Greek Captain.

*Translation of the annexed Greek letter.**

Sir,

I perceive that your colleges here do not differ in the least from those of England as to their studies either in philosophy or literature. But, what shall I say? Though they are adorned with the higher sciences and the languages, and possess so much learning, yet I have heard the *Greek Language* read with an irregular pronunciation of the syllables, with false accentuation, without proper cadences, and, in short, without the least Greek utterance. With some reason then I may observe, that instruction in this is yet wanting; and I have therefore presented myself before this illustrious nation, and have engaged to teach, to any who may desire it, the *Greek pronunciation;* being myself a

* See Pl. IV.

native of the Peloponnesus, and from the city anciently called *Pylus*, but now *Navarinos*, in which same country I learnt the language and pronunciation.

Further I will observe, that besides the pronunciation, if any shall desire to learn to *write*, I will instruct them in my mode of writing, which is conformable to the *writing letters* which are now used in our colleges. These; and I with all respect I remain,

your humble servant,

NICHOLAS TZIKLITEERA.

Boston, the 2d Feb'y, 1818.

NOTE.

Page 256, *line* 3 *from the bottom*. The passage from *Cratinus* is commonly cited as I have here given it; and so it stands in the *Etymologicon Magnum*, p. 196, *edit. Sylburg*. and in *Phavorinus*, p. 1186. But in *Suidas* (as quoted by *Constantine*) the first part of the line is—Ὁ δη λοισθιος, etc. This difference may probably be accounted for, by the ι and οι being both pronounced alike. Which of the two is the true reading it may not be easy to determine; nor is it of any consequence in the present case. It may, however, be observed, that the latter reading is supported by the Lexicon of *John Zonaras*, p. 387, which has—Ὁ δε λοισθιος, etc. This valuable work, as well as the long desired Lexicon of *Photius*, after slumbering for centuries among the manuscripts of the libraries of Europe, has lately been given to the public by the indefatigable zeal and perseverance of the scholars of Germany. I call it *Zonaras*' Lexicon, after the editor, *Joh. Aug. Henr. Tittman*, who gives several reasons of some weight for ascribing it to that author. Nor does the circumstance mentioned in his

Prolegomena, p. 33, affect the probability of his supposition; though the learned editor seems to be at a loss how to account for it. He observes of one of his Manuscripts—"In folio singulari, quod post thecam ad compacturam Cod. pertinet, legitur: *Arsenii cujusdam Lexicon Græcum.* Hinc etiam in Catalogo *Nesselii* impresso et deinde in bibliotheca Fabricii sub titulo illo commemoratur. [Vol. vi. p. 631, *ed. nov.* Nessel. part iv. p. 74.] Sed quæ causa fuerit, cur *Arsenio* nescio cui, hoc opus tributum sit, *frustra rescire cupio*, neque de *Arsenio* quodam, Grammatico aut Lexici auctore, mihi quidquam constat." The source of this blunder in the MS. (for a blunder it certainly must be) is, I think, discoverable upon examining the Lexicon. The words are all arranged in five classes—masculine, feminine and neuter nouns, verbs and adverbs, which last class comprehends the other parts of speech. Now it happens, that the first class of words under the letter *A*, consists of *masculine* nouns, and it is accordingly entitled Αρσενικον; which word, being seen at the head of the MS. would be mistaken, by some owner of it, for the name of the author. If the work had begun with the class of *feminine* nouns (Θηλυκον) we might perhaps have had *Thelycus*' Lexicon.

ERRATA.

Page	36	*line* 17	*for*	(F) *read* (Q).
	51	6		Equations *read* equation.
	66	5		*m*, (T — S) *read* *m*. (T — S).
	68	24		second *read* first.
	71	9		L′ — L *read* L′ — L^{vi}.
	237	28		λίμος read λιμὸς.
	"	"		λοίμος read λοιμὸς.
	242	12		*é*, *ai*, *oi*, *ait*, *oit*, read *ê*, *aî*, *ois*, *aits*, *ets*.
	255	17		*balucum* read *balneum*.

pt. 2

XVII.

On the Meteor which passed over Wilmington in the state of Delaware, Nov. 21, 1819.

By NATHANIEL BOWDITCH, LL. D.

On the 21st of November 1819, a remarkably large and brilliant meteor passed over Wilmington, Delaware, moving in a direction between South and West, and at so great a height that it was seen at the same time in Danvers, Massachusetts, and in Baltimore, Maryland, by persons above 380 miles distant from each other. It was also noticed at several intermediate places, and some accounts of it were published in the newspapers soon after its appearance. All these observations concur in making it at a much greater height above the earth's surface, than the famous Connecticut meteor, which deposited so many heavy stones, and the phenomena attending on both meteors were in many respects very much alike, indicating a common origin and similar properties, though no stones were *known* to have fallen from the present meteor. Ignorant as we now are of the origin of these bodies, it becomes important, for the purpose of obtaining a true theory, to collect and preserve all the facts relative to them, and to ascertain, as nearly as possible, their heights, directions, velocities, and magnitudes. With this view I have collected such observations of this meteor as have come to my knowledge by means of the public papers and by private communication, and have made such

deductions as seem to be warranted by the combination of all of them. Observing however that a very great degree of accuracy is not in general to be expected in these results, but merely a considerable approximation towards the true elements, on account of the degree of uncertainty which almost always attends such observations, which are suddenly made, in a moment of surprise, upon a body having a very rapid motion. In the present instance there were a considerable number of observations, which generally tended to confirm each other.

1. The most particular account of this meteor I have seen is that published in the American Watchman (a Delaware newspaper) in the following terms. "Standing in the open air within the borough [of Wilmington, Del. lat. 39° 45′, long. 75° 31′ W. Greenwich, nearly,] we were surprised by a sudden flood of light, sufficient to enable us to read the smallest print. Casting the eyes around, we discovered a fire ball in motion in a direction east north east 50° or 60° above the horizon: continuing its course, it passed a little to the south of our zenith, towards the opposite point of the compass, and at about 30° above the western horizon it became invisible. This body was perhaps about two seconds in progression before we saw it; from which we infer that it first appeared about 30° above the eastern horizon [allowing 25° to 30° for its motion in that time]: hence it travelled, whilst within view, about 120° in the heavens, and in a period, we believe, of not less than five nor more than ten seconds. The size of the body, when first observed, might be about half that of the full moon; the tail which projected from it was of a conical shape, well defined, and extending, from the ball to the apex, about 4° or 5°. No sparks were observed. The whole appeared to be a compact mass of fire, in which was combined all the redness of

Mars and the softer light of the moon. The whole appearance was sublime beyond description. At about 30° from the zenith westward, it began rapidly to decline, and in two seconds became to appearance extinct; its tail in the mean time lengthening to 10° or 15°, forming a narrow red streak of evanescent fire. About three minutes after it had disappeared, a noise was heard resembling cannon or distant thunder, and in a westerly direction."

2. In the same paper were given other observations made at a place $1\frac{1}{4}$ mile S. E. from Wilmington. "A very bright meteor was seen to pass over this place Nov. 21, 1819, at 20′ before 7 P. M. It arose from the N. E. and travelled in a direction S. W. leaving a tail of fire behind it, which marked its path through the heavens for a very considerable distance. Its size was equal to that of the moon, its shape that of a blazing torch, and its rapidity such as to pass through our zenith in about 30 seconds. Its first appearance was marked by a quantity of falling sparks; the same phenomenon preceded its exit, and two minutes after losing sight of it, a rumbling noise, like distant and protracted peals of thunder, was heard for upwards of 90 seconds, in the direction of its flight. Its brilliancy was such, and such the light produced by it, that it was equal to that of the sun when just emerging from the horizon. The greatest light was obtained twenty degrees after its passage across our meridian. Observations made in Wilmington do not make its parallax very sensible, which shows its height to be at least twenty miles. Its disappearance was at about 25° above our horizon."

3. The observations at Baltimore (lat. 39° 17′ long. 76° 37′) obtained by an obliging friend (about two months after the appearance of the meteor) from a gentleman of observation and intel-

ligence who was in Baltimore at that time, and had a perfect view of it through its whole course, are as follow.

The first appearance was at 5^{h} 55′ P. M. position N. E. altitude 45°. Its course was south, inclining west; or perhaps S. W. arch passed over about 75°. At the time of its disappearance its position was S. E. altitude 25°. When first seen, it appeared for a moment stationary; but was almost instantaneously in rapid motion, which seemed to increase, though very little till it burst. Its size was half the diameter of the moon. Colour of a brilliant lustre, like the star Sirius, without any reddish appearance. A moment before it disappeared, a lucid ring separated itself from the body of the meteor, and became as large as the moon. The body of the meteor within the ring was not diminished, but changed to a reddish colour. But this appearance of the ring was almost instantaneous at the moment the whole disappeared. No tail was seen, and it looked, through its whole course, precisely like an uncommonly large star. It was so brilliant as to throw a strong light into the windows of houses in the city. The time of its whole visible course was not more than half a minute. No explosion was heard in Baltimore; but a gentleman who was at that time in Kent County informed me the explosion was like the rumbling of a wagon over a smooth hard road.

The following accounts were also published in the newspapers at Baltimore. "A very luminous meteor passed over the city Nov. 21, 1819, in the evening about half past six o'clock. Its course was from N. E. towards S. W. Its apparent size increased as it approached, till it appeared nearly as large as the moon, when it exploded. The light it diffused was equal to that of strong lightning."—"A gentleman who resides a few miles N. E.

of the city, represents the luminous body to have resembled iron in a state of fusion—that it appeared of considerable length, and travelled from the north-east towards the south-east, [that is, it appeared in the north-east and disappeared in the south-east.] A few seconds after its disappearance, a noise was heard like the firing of cannon, four times in quick succession, which was followed by a rumbling noise, like that of several carriages passing over a long bridge. The light which it emitted completely obscured that of the moon and stars, which before its appearance were uncommonly brilliant. It was first observed about ten minutes after six o'clock."

The altitude of the meteor observed at Baltimore 45°, seems to require a correction similar to that made in the Wilmington observation [25°,] on account of not seeing it at the first instant; this would make the altitude 20°, which we shall assume for the true elevation.

4. In the public papers it is stated that, on the evening of Nov. 21, 1819, the meteor was seen near Salem in West Jersey, at about half past six o'clock, and described an arch of 120° or 130°. "Its colour like iron in a state of perfect fusion. It was visible 6″ or 7″, and its course nearly from E. N. E. to W. S. W. Two or three minutes after its disappearance a tremendous sound, followed by a long rumbling, proves this meteor to be one of that singular kind which deposites heavy stones. It was seen and distinctly heard for a space of at least 30 miles in diameter; how much further we have not learned."

5. It is mentioned in the newspapers, that on the 21st Nov. 1819, at about 7 o'clock, a brilliant meteor passed over Trenton, (lat. 40° 13′ N. long. 74° 47′ W.) in a direction from N. E. to S. W.

6. This meteor was seen and carefully examined by John W. Proctor Esquire, in Danvers, Massachusetts, (lat. 42° 34′ N. lon. 70° 56′ W.) who gave me the following account. "On the evening of Nov. 21, 1819, between the hours of 6 and 7, I saw a meteor much larger and more brilliant than any I have ever before seen. Immediately after, I looked at my watch, and the time was 6^h 20′; but there might possibly be an error of 15′ in the regulation of the watch. I was walking in a central part of the town of Danvers, *in the direction in which the meteor appeared, and think it probable that I saw it when it first appeared.* The moon at that time was about five days old, and shone bright. The meteor was much more brilliant and luminous than the moon. The form of the meteor was oval or oblong, the longest diameter being in the direction of its motion. Admitting the apparent diameter of the moon to be 30′ [32′], I should think the apparent length of the meteor was 9′ [9′ 36″], and breadth 6′ [6′ 24″]. When I first saw it, it was about 5° above the horizon. Its motion was rapid, inclining to the west, so that the arch of a great circle of the sphere, which it appeared to describe, intersected the horizon in an angle of about 75°. The land over which it appeared was elevated about $1\frac{1}{2}$° above the place on which I stood, at the distance of one third of a mile. The point of the horizon in which it disappeared was from me in the direction S. 59° W. The appearance of the meteor was vivid and brilliant in the highest degree; resembling the burning of charcoal, phosphorus or iron in oxygen gas. Sparks, some of which were apparently of the size of the larger stars, appeared, thrown off from the meteor in every direction. It resembled a piece of red hot iron when first taken from the furnace. The time that I saw it, I cannot accurately estimate.

It could not have been more than five seconds, and possibly not more than two or three."

It may be observed, that Mr. Proctor published in the Salem Gazette of Dec. 2, 1819, an account nearly similar to the above, the altitude when first discovered was however estimated "at about 10° above the horizon in a W. S. W. direction." As he recollected precisely the place in the road where he observed the meteor, and noticed its disappearance near a small bush on the elevated land he speaks of in his account, I requested him to observe its bearing and altitude accurately with a theodolite, which he did, and found it as above to be S. 59° W. or S. 54° W. corrected for the variation instead of W. S. W. and the altitude of the meteor, estimated by directing the telescope to the part of the heavens where it was supposed the meteor first appeared, was found to be 5°. If the object was not discovered at the very first moment, it would be necessary to increase this angle, and on that account it would perhaps be better to take an intermediate quantity between both his estimates, we shall therefore assume $7\frac{1}{2}°$ for the apparent altitude of the meteor at its first appearance in Danvers, which would make the whole visible arc described about 6° 12′.

7. The effect of the attraction of the earth upon the meteor during its appearance may be neglected, and we may suppose it to have moved in the straight line joining the two extreme points of its actual path. The error of this supposition will be far within the limits of the errors of the observations, as will appear evident by making a rough estimate of the deflection of the body from the tangent of its path supposing it to be a parabola, which will be sufficiently accurate for the purpose of illustration. The duration of the appearance of the meteor, by the mean of all the observations was 16 seconds, during which time the body would have

fallen by the force of gravity, (estimated in the usual manner, neglecting the resistance &c.) through the space of 16×16^2 feet. This quantity represents the deflection from the tangent; and the greatest distance of the curve from the chord line connecting the two extreme points would be only a fourth part of it, or 4×16^2 feet, which is nearly $\frac{1}{5}$ of a mile, and this variation at the great height of the meteor would not affect its apparent place observed in the heavens half a degree at its maximum, and generally would be much less. To determine, therefore, the place of the meteor, with as much accuracy as can be attained by these observations, it will only be necessary to find the places of its appearance and disappearance. The method of doing this is explained in my paper on the Connecticut meteor given in the Memoirs of the Academy, and after various calculations I have assumed the following places of the meteor as those which, on the whole, would best satisfy the aggregate of the observations.

	At its appearance.	At its disappearance.
Latitude of the meteor -	40° 23′ N.	39° 11′ N.
Longitude of the meteor -	74 34 W. Greenw.	76 03 W. Greenw.
Height above the earth's surface	38 miles.	22 miles.

The azimuths and altitudes of the meteor and its distances from the different observers, expressed in statute miles of 5280 feet, were computed by means of the preceding values, by the usual rules of trigonometry, and inserted in the following table with the observed places, in order to give at one view the differences between the observed azimuths and altitudes.

	Azimuths.			Altitudes.			Distances of the Meteor from observer.	Whole arch described by the meteor while visible.		Inclination of path to horizon	
	Obs.	Calcul.	Diff.	Observ.	Calcul.	Diff.		Observation.	Calcula.	Obs.	Calculat.
First appearance at	°	° ′	° ′	° ′	° ′	° ′	Miles.	° ′	° ′	°	° ′
Danvers	233	232 29	0 31	7 30	7 25	0 5	245	6 12	6 7	75	72 25
Trenton	45	44 41	0 19				43				
Wilmington	{ 45 67½	48 38		30 0	29 14	0 46	77	120	125 25		79°
Baltimore	45	53 48	8 48	20 0	14 59	5 01	139	75	48 01	or 11 degrees from the zenith of Wilmington. This and the Danvers Inclination agree well with the observations.	
Salem W.J*		40					82	{ 120 130	125 06		
Disappearance at											
Danvers	234	230 32	3 2[illegible]	1 30	1 18	0 12	358				
Trenton	225	223 44	1 1[illegible]				101				
Wilmington	{ 225 247½	216 10		30 0	24 01	5 59	53				
Baltimore	135	102 39	32 21	25 0	35 0	10 0	38				
Salem, W.J.		232					49				

These calculated places agree remarkably well with the observations at the first appearance of the meteor, but in the observations at the time of the disappearance, there is a considerable discrepance, and it is not possible wholly to reconcile the observations at Baltimore with those made at other places. This difficulty may have arisen partly from the circumstance that the Baltimore observations were not given immediately upon the appearance of the meteor, when the recollection of it was fresh in the memory, but after the lapse of several weeks, when some of the circumstances might have been forgotten; and of course greater differences were to be expected in them than in the other observations. In calculating the apparent altitudes of the meteor, the terrestrial refraction was supposed to be equal to $\frac{1}{14}$ part of the angle formed at the centre of the earth by the lines drawn to the places of the meteor and the observer. The elevation of the meteor above the horizon of Danvers was by this table 1° 18′ at the time of its disappearance, and as the elevation of the land in

* The numbers for Salem (W. J.) were estimated roughly by a graphical projection.

that direction was 1° 30′, it must have been hid by the land a fraction of a second of time before its actual disappearances at other places.

From these assumed places of the meteor, it would follow that *its apparent direction over the earth's surface* (neglecting the annual and diurnal motion of the earth) *was nearly* S. 44° W. The distance of the extreme points of its path was $117\frac{1}{7}$ miles, *the length of its curvilinear path while visible being greater than this quantity. Its height above the earth's surface decreased from 38 to 22 miles while it continued visible. The duration of its appearance, by the mean of all the observations, was about 16 seconds, consequently its velocity was about $7\frac{1}{3}$ miles per second*, which is considerably greater than would be required to make a body move like a satellite about the earth in a circular orbit. It is also a greater velocity than a body would acquire, by the force of gravity, in falling to the earth from an infinite distance, and if a body were projected vertically with that velocity, and the resistance of the air to cease, it would never fall back again to the earth.

With the mean distance of the meteor from Danvers and its apparent diameter by observation 6′ 24″, the real diameter would be 2966 feet. The distance at its first appearance at Wilmington under the angle 16′, would make its real diameter 1887 feet. The mean distance from Baltimore and the apparent angle under which it appeared (by the mean of both observations made there) 12′, would make its real diameter 3271 feet. The mean of these three estimates makes *the actual diameter of the meteor equal to 2710 feet, or about half a mile.* The oblong form observed at Danvers was, without doubt, produced by the tail of the meteor, which must have appeared very short at that place on account of the oblique position in which it was viewed. When the tail was

visible with great splendour near the zenith of a spectator at Wilmington, it would have been much less noticed at Baltimore, because its direction would have fallen nearly in a line with the body of the meteor, which would have partly prevented its being seen. As the meteor began to diminish in lustre, the position at Baltimore became more favourable, and then a lucid ring was visible there, but was not seen at Wilmington. Both these observations are however perfectly compatible with each other; for if the plane of the ring was a vertical one passing through the path of the meteor, its edge only could have been seen at Wilmington, while the whole circle could have been seen at Baltimore; in the same manner as Saturn's ring might disappear from our view, although in its greatest opening as observed from another planet.

It may be observed, that the height we have assigned to the meteor is in some measure confirmed, by the time elapsed between the disappearance of the meteor and hearing the report of it, which by the observation at Wilmington and Salem (W. J.) was from two to three minutes, and by supposing sound to move at the rate of 1142 feet per second, it would correspond to a distance of from 26 to 39 miles from these places.

XVIII.

Occultation of Spica by the Moon, observed at Salem.

By NATHANIEL BOWDITCH, LL. D.

This occultation was nearly central on the morning of the fifth of February, 1820. The weather was remarkably clear, and the observations of the immersion and emersion (made with a four-feet achromatic telescope) were remarkably good; but the weather had previously been so inclement that the regulation of the chronometer was not so accurate as I could have wished, and there may be an uncertainty of four or five seconds in the times.

The observations were,

Immersion	0^h	$12'$	$13''$	apparent time.
Emersion	1	22	38	" "

The latitude of the place of observation (near the north meeting-house in Salem) is $42° 33' 30''$. The longitude $53''$ in time East from Cambridge, or $4^h 43' 37''$ W. from Greenwich. Using these and the latitudes of the moon given in Burckhardt's tables, also the place of the star as in the Nautical Almanac for 1820, as it was found by the Astronomer Royal, Mr. Pond, the correction to be applied to the moon's longitude by Burckhardt's tables would be $+ 9''.2$.

XIX.

On a mistake which exists in the calculation of Mr. Poisson relative to the distribution of the electrical matter upon the surfaces of two globes: in vol. 12 of the "Mémoires de la classe des sciences mathématiques et physiques de l'Institut Impérial de France."

By NATHANIEL BOWDITCH, LL. D.

In the second memoir of Mr. Poisson, published in the above volume (which the reader of this article ought to have lying before him) is given a series to find the thickness of the electrical stratum upon the surfaces of two globes brought nearly in contact with each other. In the course of this calculation when finding the value of S′ (page 245, line 16) the integral $\int \frac{t^3\,dt}{c^{2\pi t}-1}$ is multiplied by the factor $18 - \frac{5}{3} + \frac{4a}{a+b}$, instead of which the simple factor $\frac{61}{3}$ ought to be used. This affects the calculation in several of the expressions in the subsequent pages of that work. Thus (in page 246, line 5) the two first terms of H become $-\frac{5}{12b} - \frac{\delta^2}{6}\left(\frac{7}{240} - \frac{5a}{16(a+b)} - \frac{a^2}{8(a+b)^2}\right)$, being exactly the same, except in the signs, as the two first terms of H′, (page 247, line 18,) so that when these terms are added together, to obtain the value of y, (page 248, line 3,) the coefficient of $h\,\delta^4$ vanishes, as well as those of h' and $h'\,\delta^2$, leaving only the term $\mathrm{H}\,h'\,\delta^6$ (af-

fected with the *sixth* power of δ depending on h'.) In like manner the term $\frac{h'\delta^4}{60(a+b)}$ vanishes from the value of z, (page 248, line 10;) and the value of $y = z$ (page 267, line 20) instead of being proportional to the *fourth* power of δ, is nearly as the *sixth* power, and becomes $y = z = \frac{HA\delta^6}{A'}$. The expression of y (page 268, line 9) instead of being $\frac{2\alpha^2}{15a^2 \log 2}$. A, becomes $y = \frac{64. H\alpha^3}{a^2. \log 2}$. A, or, in other words, the thickness of the electrical stratum (upon the nearest points of the surfaces of two equal spheres, equally electrised, and placed at very small but variable distances from each other) is proportional to the *cube* of the distance of the surfaces, instead of the *square* of the distance, as is stated in the memoir. These are the most important corrections to be made in the memoir in consequence of this mistake.

XX.

On the Orbit of the Comet of 1819.

By ALEXANDER M. FISHER, A. M.

PROFESSOR OF MATHEMATICS AND NATURAL PHILOSOPHY IN YALE COLLEGE.

Communicated in a letter to the Hon. Nathaniel Bowditch.

This body was first observed, in the United States, on the evening of the second of July : in right ascension 102°, declination 42° N. Its lustre was nearly equal to that of a star of the first magnitude, when viewed at no greater distance from the horizon. The length of the tail, on the morning of July 6th, the moon being below the horizon and the air perfectly clear, was judged to be somewhat greater than that between the two stars α and β Aurigæ. The direction was marked on the evening of July 13th, as being towards a point between ε and ζ Ursæ Minoris : hence it must have pointed, as usual, nearly opposite to the sun. Near the body of the comet it was unusually narrow and well defined ; but its boundaries soon diverged, and became indistinct. The head, as viewed with telescopes of different powers, presented a disk of very sensible magnitude, but too ill defined to admit of exact measurement. With a Gregorian reflector of five inches aperture and a magnifying power of about 70, the light was very perceptible on the evening of the 13th, through a diameter of two minutes ; and the utmost extent of the visible coma was perhaps

nearly twice as great. On the 19th, when its brightness to the naked eye had greatly diminished, the greatest perceptible diameter was $2\frac{1}{4}$ minutes. The adjustment of the focus was made by looking at Jupiter; and the micrometer employed in these measurements gave the diameter of Jupiter within about $2''$ of the truth.

After the 12th of July, the brightness of the head began sensibly to decline, and the length of the tail gradually diminished. The following table contains the estimated brightness compared with that of surrounding stars, and the length of the tail, at several successive times, before its disappearance:

Time.	Magnitude.	Length of the tail.
July 3	1	8° or 9°
— 13	2.3	8°
— 19	4	5°
— 25	5	2° or 3°
— 31	6	1°

After the morning of July 31st, it was not seen in New Haven. With a forty inch refractor, it was supposed to have been seen in New York, as late as the 10th of August.

On the morning of July 6th, a series of observations on the distances of the comet from the most convenient fixed stars was commenced in the Lyceum of Yale College, and continued, when the state of the atmosphere would permit, till it disappeared. These observations were made when the comet was between 5° and 10° above the horizon, and therefore, independently of the necessary imperfection of the instrument employed, are liable to some uncertainty, on account of the irregularity of refraction.

A first approximation to the elements of the orbit was deduced from five observations made between July 6th and 28th. The

results were published in a New Haven periodical paper, under the date of July 30th, and are as follows :

Perihelion distance - - - - -	,3416
Time of passing the perihelion, June 27th, 8h even. mean time, N. Haven.	
Inclination of the orbit - - - - -	80° 53′
Longitude of the ascending node - - -	272 32
Place of the perihelion - - - - -	285 30½
Motion direct.	

These elements were obtained by a simple graphical process, which is believed to possess some advantages over those usually described in astronomical treatises.

The late comet appeared under circumstances peculiarly unfavourable to a determination of its orbit by the approximating methods. In addition to the short time of its continuance in view, the small arc of its geocentric motion, and its nearness to the horizon, the position of its orbit with respect to the earth was such, that a small error in its geocentric position would produce a comparatively large one in some of the elements. Observations taken soon after it appeared would have been peculiarly valuable, on account of the rapid motion in latitude ; but none could be made in New Haven with instruments of sufficient accuracy to deserve any reliance in correcting the orbit, till July 6th ; and these could not be employed, on account of the near approach of the angle made by the radius vector of the comet and the visual ray of the earth, to 90°. Observations made near the 13th could not be advantageously employed, on account of the near approach of the *projection* of this angle on the plane of the ecliptic, to 90°.

The observations which were selected, as possessing, on the whole, the most advantages for correcting the first approximation, were those made on the evenings of July 9th and 19th, and on the morning of July 31st.

In calculating the geocentric latitudes and longitudes of the comet, the following method was pursued. The mean right ascensions and declinations of the stars employed were taken from the most approved tables, and corrected for precession, aberration, and nutation, in such a manner as to give their apparent right ascensions and declinations at the times of observation. The altitudes of the comet and stars were found with sufficient accuracy for determining their refraction, which was corrected for the state of the barometer and thermometer. The parallax of the comet was nearly estimated from the approximate elements, and applied to its refraction. The true distance was then calculated from the apparent in a mode analogous to that employed for clearing lunar distances. With the aid of the true distances thus found, and rendered simultaneous by the application, to one of them, of a proportional part of the daily motion, the right ascension and declination, and from these, the latitude and longitude were determined. To obtain the true from the apparent latitude and longitude, a correction for aberration was necessary. This was deduced from the daily geocentric motion, and the distance of the comet from the earth, (known nearly from the first approximation,) by the method given, Vince's Ast. vol. i. page 336. The latitudes and longitudes of the comet, and the longitudes of the sun, obtained by adding 20″ to those given in the Nautical Almanac, are subjoined.

Time.	Lat. N	Longitude.	Long. ☉
	° ′ ″	° ′ ″	° ′ ″
July, 9.3972	27 7 37	106 39 41.5	106 56 35
19.3924	30 4 5	108 23 5	116 28 42
30.6236	30 37 7	112 20 58	127 12 55.5

Two successive applications of the method of Laplace gave the perihelion distance, 0.3366878, and the time of passing the perihelion, June 27^d.294973. With these numbers, the anomalies between the times of observation were calculated, and compared with those deduced from the observations. The anomalies between the second and third observations agreed precisely; those between the first and second differed but 40″; so that it was thought superfluous to repeat the operation.

The remaining elements were calculated, and the whole were as follows:

Perihelion distance - - 0.3366878

Time of passing the perihelion, June 27th, 7^h 4′ 23″ mean time at New Haven, or 11^h 56′ 28″ mean time at Greenwich.

Inclination of the orbit - - 80° 56′ 17″

Longitude of the ascending node - 273 39 18.4

Place of the perihelion - - 286 21 33

Motion direct.

To ascertain whether any considerable change in these elements would be required by the other observations, the geocentric latitudes and longitudes of the comet were calculated for the times of *all* the observations made in this place with the sextant. The following table, which contains the results, together with the latitudes and longitudes for the same times, deduced immedi-

ately from the elements, presents an agreement as close, perhaps, as could be expected, even supposing the elements exact.

Time.	Lat. Calc.			Lat. Obs.			Error.	
d	°	′	″	°	′	″	′	″
5.6229	23	58	15.7	23	55	24	+ 2	51.7
9.3972	27	7	32.4	27	7	37	— 0	05.6
13.3868	28	53	0	28	53	24.6	— 0	24.6
16.3889	29	37	13	29	38	24.3	— 1	11.3
18.3861	29	56	31.7	29	58	18.5	— 1	46.2
19.3924	30	4	3.6	30	4	5	— 0	01.4
25.3924	30	29	31.6	30	29	31.3	— 0	00.3
30.6236	30	37	7	30	37	7	0	00.0

Time.	Long. Calc.			Long. Obs.			Error.	
d	°	′	″	°	′	″	′	″
5.6229	101	26	55.6	101	25	41	+ 1	14.6
9.3972	103	39	38	103	39	41.5	— 0	03.5
13.3868	105	42	12.2	105	45	1.5	— 2	49.3
16.3889	107	4	58	107	5	57.3	— 0	59.3
18.3861	107	56	15.5	107	56	17.8	— 0	02.3
19.3924	108	21	5	108	23	5	— 2	00
25.3924	110	36	56.6	110	36	56.6	+ 0	04.1
30.6236	112	20	58	112	20	58	0	00

The distances of the comet from the earth were calculated for each of the above times, and were found to be,

0.906831	1.289453
1.027576	1.315768
1.149605	1.460460
1.235418	1.570855

the mean radius of the earth's orbit being taken as unity.

If the correctness of the foregoing elements be admitted, the comet, when it crossed the ecliptic, must also have passed over the sun's disc. The particulars of this transit as determined from the elements, are given below :

True time of passing the ecliptic, June 25th,	$11^h\ 59^m\ 18^s$
Sun's apparent longitude, - -	93° 31′ 45″½
Log. earth's distance from sun, - -	.0070594
Log. dist. comet from sun, - - -	1.5325761
Log. Hor. motion in min. round the sun, -	1.2407914
Obliquity of the motion to the line of common section of the orbit and ecliptic, - - - -	83° 38′ 53″
Log. Hor. motion reduced to a perpendicular to the line of common section, - - - -	1.2381170
Hor. motion as seen from the earth. - -	8′.7309
Hor. motion of earth about the sun, - -	2′.3847
Do. about the comet, - - - -	3′.58808
Obliquity of the apparent orbit to the ecliptic,	75° 36′ 17″ E.
Angle of apparent path with a secondary of the ecliptic passing through the sun's centre, -	88° 51′ 31″ W.
Diff. of heliocentric long. of comet and earth,	1′ 17″
True elongation of comet from ⊙, -	0′.64689 E.
Effect of aberration, - - - -	—.21462
Apparent elongation at time of ☍, - -	0′.43227
Effect of aberration on time of ☍, - -	$+5^m\ 24^s$
Sun's semidiameter—Irradiation 3″.2, - -	15′ 42″.1
Half duration of transit, - - -	$109^m.209$
Mean time of apparent beginning, June 25th,	$10^h\ 15^m\ 20^s$
Do. of end, - - - - - -	13 53 44

The transit of a comet over the sun's disc is a phenomenon of rare occurrence. Lalande remarks that it had never been observed at the time he wrote. From a statement, however, in the Journal de Physique, (Feb. 1798,) it appears probable that a body,

seen passing over the sun by M. Dangos, on the 18th of January, 1798, was of this class. It was a round, well defined spot, and continued on the disc of the sun twenty minutes.

Franklin, Mass. Oct. 1819.

XXI.

Elements of the Comet of 1819.

By NATHANIEL BOWDITCH, LL. D.

On the evening of the third of July 1819, I saw this comet for the first time at Salem; in the direction N. N. W. and very near the horizon, but no observations were made till the following evening, when distances were measured from Lyra, Dubhe, and the Polar Star. Similar observations were made on the following evenings when the weather was favourable, till the 22d of the same month, during which time the comet passed obliquely through the body of the constellation Lynx, from the upper part of the left thigh to the middle of the back, describing nearly an apparent arch of a great circle of 12°. The long duration of the twilight, the constant haziness of the weather, and the obstructions from the trees and houses, in the only place where I could conveniently view the comet, rendered the observations of it difficult, and somewhat uncertain, particularly towards the latter part of its appearance. After the 22d of July it was so very hazy that the comet could not be seen with sufficient distinctness to admit of a tolerably accurate observation. Several occupations prevented me from attending to the reduction and calculation of these observations till near the time of the disappearance of the comet, and then by combining three of the observations I obtained the approximate elements published in the Salem Gazette of Aug. 24.

Afterwards I received the observations of Professor Farrar at Cambridge, and those of the Hon. Walter Folger at Nantucket and Falmouth, which were made under the same unfavourable circumstances with respect to the weather, and liable to the same uncertainty from the irregularity of the refraction in a body observed so very near to the horizon. Combining these observations with my own I obtained the following elements, published in the Salem Gazette of September 28; which give in general the longitudes and latitudes within one or two minutes.

Elements of the Orbit.

Perihelion distance 0.3363866 (the sun's distance from the earth being 1.)

Time of passing the perihelion, June 27^d 13^h $30'$ $20''$. Mean time Greenwich.

Inclination of the orbit to the ecliptic	-	80°	56′	7″
Longitude of the ascending node	- -	273	54	32
Place of the perihelion on the orbit	-	286	27	11

Motion *direct.*

By these elements it appears that the comet passed nearly over the centre of the sun's disc (which is a very unusual occurrence) at about 7 o'clock in the morning of June 26th at Greenwich.

After these calculations had been made I received the observations of Professor Fisher at New Haven, which I found in general to agree very well with mine. He was so fortunate as to observe the comet as late as the 30th of July, and I had once intended to revise the elements by means of all the observations, but upon reflection concluded not to do it, supposing the above elements to be as accurate as could be obtained with observations, made in this manner under such unfavourable circumstances.

XXII.

On the adoption of a uniform Orthography for the Indian Languages of North America.

By JOHN PICKERING, A. A. S.

It is remarked by Sir William Jones, in his elegant *Dissertation on the Orthography of Asiatick Words,* that "every man, who has occasion to compose tracts on Asiatick literature, or to translate from the Asiatick languages, must always find it convenient and sometimes necessary, to express *Arabian, Indian,* and *Persian* words or sentences, in the characters generally used among *Europeans;* and almost every writer in those circumstances has a method of notation peculiar to himself: But none has yet appeared in the form of a complete system, so that each original sound may be rendered invariably by one appropriate symbol, conformably to the natural order of articulation, and with a due regard to the primitive power of the *Roman* alphabet, which modern Europe has in general adopted." This accomplished scholar then adds—that "a want of attention to this object has occasioned great confusion in History and Geography;" and "that the ancient *Greeks,* who made a voluntary sacrifice of truth to the delicacy of their ears, appear to have altered by design almost all the oriental names, which they introduced into their elegant, but romantick histories; and even their more modern Geographers, who were too vain, perhaps, of their own language to

learn any other, have so strangely disguised the proper appellations of countries, cities, and rivers in Asia, that, without the guidance of the sagacious and indefatigable *M. D'Anville*, it would have been as troublesome to follow Alexander through the *Panjàb* on the Ptolemaick map of *Agathodæmon*, as actually to travel over the same country in its present state of rudeness and disorder."*

The inconveniences and confusion, which are here so strikingly described in the case of the *Asiatick* languages, are now beginning to be experienced by writers upon the Languages and History of the *Indian nations of America*. In this latter case, however, we are relieved from one embarrassment, which is felt in the case of the Asiatick tongues; for in those, as there is already a written character, and an established alphabetic arrangement of the elementary sounds, which does not in every instance correspond with the order of our Roman alphabet, we experience a constant struggle in the mind, when we attempt to write *Asiatick* words in our letters, arising from that natural desire which we feel to represent each Asiatick character by one of our own, which occupies the same place in the alphabetic list. But in the languages of the *American Indians*, we have only to ascertain, in the first place, every elementary sound, and then arrange the letters, by which we may choose to represent those sounds, in the order of our own alphabet.

Until within a few years past, indeed, these neglected dialects, like the devoted race of men, who have spoken them for so many ages, and who have been stripped of almost every fragment of

* Dissertation on the Orthography of Asiatick words in Roman letters; in Sir W. Jones's Works, vol. i. p. 175, 4to edit.; and in the Asiatic Researches, vol. i. p. 1.

their paternal inheritance except their language, have incurred only the contempt of the people of Europe and their descendants on this continent; all of whom, with less justice than is commonly supposed, have proudly boasted of the superiority of their own more cultivated languages as well as more civilized manners. But, at length, in consequence of the impulse originally given by the Empress Catherine of Russia, and subsequently by the illustrious Adelung, Vater, and other German literati, whose indefatigable diligence and zeal will not suffer the remotest corner of the globe nor the most uninviting department of human knowledge to remain unexplored, we are beginning to inquire into the history and character of our degraded fellow-men of this continent, and to investigate the wonderful structure of their various dialects; which, indeed, to the philosophical inquirer, will now perhaps be found to be the most curious and interesting of all the languages of man.*

* My learned friend, Mr. Du Ponceau, first directed my attention to the fact here stated respecting the Empress Catherine; and I am indebted to him for the perusal of that interesting account of the eminent services rendered to literature by this extraordinary princess, entitled "Catherinens der Grossen Verdienste um die Vergleichende Sprachenkunde:" which may be rendered, *The Merits of Catherine the Great in promoting the Comparative Science of Languages.* This work was published at St. Petersburg in the year 1815, by the Hon. Frederick Adelung, whom Mr. Du Ponceau, in his *Report* on the Indian Languages (p. xix.) states to be "the nephew and worthy successor of the great Adelung," and "not inferior to his predecessor." The volume contains a particular account of the extensive plan of the Empress, and the measures taken by her to obtain vocabularies of all the languages in the world. She directed her Secretary of State to write to the powers of Europe, Asia, and America; and application was accordingly made to President Washington for our *Indian* lan-

The first fruits of these inquiries in the United States have been the able and philosophical investigations of Mr. Du Ponceau,

guages; several specimens of which were accordingly furnished. But what will most surprise the reader will be, to learn that the Empress herself actually began the labour of this comparison of languages. In a letter to the celebrated Zimmerman, dated May 9, 1785, she says—"Your letter drew me from the retirement in which I had kept myself for almost nine months, and which it was difficult for me to relinquish. You will hardly suspect what I was employed about in my solitude. I made a list of between two and three hundred radical words of the Russian language, and had them translated into every tongue and jargon that I could hear of; the number of which already exceeds two hundred. Every day I took one of these words and wrote it down in all the languages I had been able to collect..... I grew tired of this hobby, as soon as the book upon Solitude was read through. But as I felt some regret at committing to the flames my great mass of papers, and the long hall, which I occupied in my hermitage, was quite warm enough, I requested Professor Pallas to attend me, and after a full confession of this sin of mine, it was agreed between us that these translations should be printed, and thus made of some use to those persons, who might be willing to occupy themselves with the idle labours of others. We are now only waiting, with that view, for some specimens of the dialects of Eastern Siberia. Whether the reader shall or shall not find in the work, striking facts of various kinds, will depend upon the feelings with which he enters upon the subject, and is a matter of little concern to me."—p. 40. Professor Pallas accordingly informed the public of Her Majesty's intentions; stating (among other things) that "she had herself made a selection of such words as were the most essential, and generally in use even among the best civilized nations...... In that selection the preference was given to substantives and adjectives of the first necessity, and which are common to the most barbarous of languages, or which serve to trace the progress of agriculture or of any arts or elementary knowledge from one people to another. The pronouns, adverbs, and some verbs and numerals, whose great utility in the comparison of languages is acknowledged, were also admitted into the collection, in order to render this Glossary more complete and more instructive."

and the interesting work of his experienced and worthy fellow-labourer, the Rev. Mr. Heckewelder. These publications alone, which are too well known to need a more particular notice in this place, abundantly show, what a vast field is now opening to those who wish to search into the philosophy of language, and to study man through the medium of his noblest and peculiar faculty of speech; and, at the same time that they do honour to our country, they will be read by the scholars of Europe, especially the learned Germans, with all that avidity which the characters of their authors will naturally excite. For my own part, I acknowledge, that they have occasioned my taking a deeper interest in this apparently dry and barren subject, than I could have believed to be possible in any one, however devoted he might be to philological pursuits; and I have, in consequence, been for a time allured from old and favourite studies, to which I had intended to allot the whole of that little leisure which I could spare from the duties of my profession.

At the very commencement of my inquiries, however, I found my progress impeded by a capricious and ever varying *orthography* of the Indian languages, not only among the writers of different nations, but even among those of the same country. I have, therefore, while examining words in one Indian dialect with a view to comparing them with those of another, been obliged to employ much time in first settling the spelling of a *written* word, in order to ascertain the sound of the *spoken* word; when I ought to have found nothing more to be necessary than to make the comparison, which I happened to have in view, between words whose *sounds* should have presented themselves upon the first inspection of their *written characters*. But with the present irregular mode ot writing Indian words, unless a reader is conversant with the

several languages of the authors, whose remarks upon the Indian dialects may fall within his observation (which remarks too are often rendered still further unintelligible by being read in a translation) he will be very likely to imagine, that the words of a single dialect, as he sees them written by a German, a Frenchman, or an Englishman, belong to languages as widely different as those of his several authors. When, for example, a mere English reader finds the familiar names of the *Creeks* and the *Choctaws,* the *Wabash* and the *Washita,* with many others, disguised by the French writers under the strange garb of *Kriques,* and *Tchactas, Ouabache* and *Ouachita,* &c.; and, among the German authors, the letters G, J, T, and Z used to express sounds which we should denote by C, Y, D, and TS, as in the words *Ganata* for *Canada, Japewi* for *Yapewi, N'mizi* for *N'meetsee,* with innumerable others; (to say nothing of the totally different sounds from ours usually given by foreign writers to all the *vowels* of the Roman alphabet)—when a mere English reader, I say, finds the very same words thus variously written, he will at first view suppose that they are the names and languages of so many different tribes of Indians.*

* In addition to these national differences of orthography, the Rev. Mr. Heckewelder (in reply to Mr. Du Ponceau's inquiries respecting the orthography of the *German* writers) mentions a very singular reason for the irregularities observable in their use of the letters *c*, *g*, and *k*: "Sometimes (says he) the letters *c* and *g* are used in writing the Delaware language instead of *k*, to shew that this consonant is not pronounced too hard; but, *in general*, *c* and *g* have been used as substitutes for *k*, *because our printers had not a sufficient supply of types for that character*." *Correspondence of Heckewelder and Du Ponceau*, p. 382. The state of our country at the present day is such, that this will no longer be an apology for the irregularity in question. It may be added, as Mr. Du Ponceau justly remarks in a letter to me, that "a German ear, unless very delicate, does not ordinarily discriminate between *k* or *c* hard, and *g*, between *p* and *b*, nor between *d* and *t*. To a German only would it have occurred, to substitute *g* for *k*."

The perplexity I felt from this uncertainty in our Indian orthography, which so much increases the labour of studies that are in themselves sufficiently dry and forbidding to most persons, led me to consider more particularly than I had ever before done, the expediency of adopting *a uniform orthography* for the Indian, as well as other languages, which have no established written characters; and I now beg leave to submit to the Academy the few reflections which have occurred to me on this subject. Imperfect and little interesting as the remarks may be, they will be received, I have no doubt, with all that candour to which they may be entitled.* They will have produced some good, if they should stimulate any of my countrymen, who have more leisure and more favourable opportunities than fall to my lot, to pursue the inquiry; an inquiry, which, while it promotes the common cause of learning, is peculiarly within the province of American scholars, and will richly reward us in the honour we shall acquire with the learned of Europe; who, it should be remembered, have a right to expect from us, and are eagerly looking for every species of information respecting this continent.

Nor will discussions relative to the languages of the American Indians be among the least interesting which we can offer to Europeans, or the least important in themselves. For, if the origin of the population of this Continent is, as all admit, a most interesting and important question; and if we can more successfully arrive at the solution of it, by tracing the progress of the various nations of men over different regions of the globe, through the

* Those, who are acquainted with Mr. Du Ponceau's Essay on English Phonology (and no scholar in our country is ignorant of that valuable publication) will perceive, that the present paper is only an application of the general principles which are there stated, to the class of the *Indian* Languages.

medium of their languages, than in any other manner (which every day's experience renders more and more probable); then it is undeniable, that a careful inquiry into the languages of a people, who were formerly the possessors of one entire hemisphere, is a subject of great moment to the inhabitants of the old as well as the new world. And, as naturalists are now investigating the structure and history of the globe itself, by collecting fragments of the component parts, from the summits of its mountains to the depths of its seas, so we must study the constitution and history of its possessor, man, by collecting specimens of him, especially of his distinguishing characteristick, language, from the most remote and barbarous, as well as the most refined portions of the race; specimens, which, indeed, with our present limited knowledge, seem to be dispersed over the earth in as extraordinary a manner, and in situations where we should as little expect to find them, as the fragments of animal and vegetable nature which we meet with in the recesses of the earth. For, as we find the productions of the ocean upon the heights of our mountains, so we discover, for example, fragments of the remote Asiatick languages imbedded, if I may use the expression, in those of the most distant extremities of Europe; as of the Sanscrit in the Russian* and other western tongues; and sometimes we find an entire language spoken by a small body of people in the midst of various others, yet totally distinct in all respects (so far as we are yet informed) from the languages by which it is thus surrounded; as in the case of the Basque language in Spain, which, as philologists inform us, has no perceptible affinity with any of the neighbouring European tongues.†

* Rapports entre la langue Sanscrit et la langue Russe. Petersburg, 1811.
† See Mr. Du Ponceau's Report on the Indian Languages, p. xxxix.

But, in order that we may successfully penetrate into this unexplored region of languages as barbarous and foreign to our modes of thinking, as the manners of the uncivilized people who use them, it is indispensable that we should adopt every practicable expedient to render our progress easy and pleasant. Now nothing is more clearly necessary at the very beginning, than some *common and systematic method of writing them;* whether our object is, to enable the learned of other countries and our own to study and compare the numerous varieties of human speech with all that exactness, which is essential to accurate and useful results, or whether we confine ourselves to the more practical purpose of possessing the means of communication with the various tribes on our borders, either with a view to the common concerns of life or the diffusion of the principles of our religion among them; and any investigation, which is so intimately connected as this with results of such importance, will not be thought unworthy of the attention of our countrymen. Nor will they, I trust, need further incitement to prosecute any inquiries whatever, minute as they may at first view appear, to which men of so much distinction in the literary world, as Count Volney among the French and the incomparable Sir William Jones among the English, have given importance and dignity by their laborious and learned researches.*

* Count Volney's elaborate work, entitled *L'Alfabet Européen appliqué aux Langues Asiatiques*, 8vo. pp. 223 (for the use of which I have been indebted to Mr. Du Ponceau since this paper was first communicated to the Academy) was published at Paris in 1819. The Dissertation of Sir William Jones, which I have already quoted, is well known to every scholar.

As various nations of Europe have already published and will continue to publish books respecting the American Indians and their languages, either with a view to the information of the learned or to the propagation of the Christian religion, it is extremely desirable, that such *a common orthography* as I have mentioned should be adopted. This would enable foreigners to use *our* books without difficulty, and, on the other hand, make theirs easy of access to us; and it would also enable the missionaries of our own and other countries (the benevolent Germans, for example, who have been so long engaged in this duty) to cooperate with the more effect in the great object of their common labours. So far too as the study of philology alone is concerned, we should derive the important advantage of being enabled to discover at once by the eye, etymologies and affinities in the Indian dialects, which with our present orthography are only discernible by the ear.

Now what are called *vowel* sounds constitute an important part of the *Indian*, as well as other languages. In *English* each of the vowels, according to its place in a word, may represent sounds, which are totally different from each other; and, on the other hand, we often represent one single sound by very different vowels, either taken by themselves or in combination with other letters. Our first vowel *a*, for example, is commonly said to have no less than four distinct powers, which are exemplified in the words, *fall, far, fat, fate*; and therefore, if we should meet with the like number of *Indian* words, in which this vowel was under the same combinations as in these English examples, we should naturally pronounce this single letter *a* (which ought to be the representative of only one sound) in four different ways. This change of power in the vowels, it is well known, does not

take place in the languages of the continental nations of Europe; but all those nations (I speak in general terms, without noticing the common distinctions of acute, grave, and circumflex accents, and other slight modifications of the fundamental sounds) preserve what may be called, in a general view of the subject, a uniform pronunciation of the vowels; a pronunciation, which is generally supposed to have been handed down to our own times, in conjunction with the letters themselves, from the Romans. I have always thought, therefore, that it would be best to adopt as the *basis* of our Indian orthography, what we call the *foreign* sounds of all the vowels; that is, the sounds which are usually given to them by those European nations, with whom we have much intercourse by books or otherwise, and who, like ourselves, use the *Roman* alphabet in their own languages. I speak with these limitations, because my object is merely *practical;* and, for all practical purposes, it will for some time to come be best to confine our views to the family of nations I have here mentioned, and to adopt an *orthography,* which, though it may not be philosophically exact, shall be attended with the least embarrassment to them and ourselves in the common use of it. We can hereafter either modify that orthography, or adopt a new one, as our extended intercourse with other families of nations may be found to require.

In conformity with this view of the subject, the general pronunciation of the vowels will be as follows:

a as in *father*
e as in *there*
i as in *machine* (or like *ee)*
o as in *note*
u as in *rule*
y as in *you* (or like *ee.)*

Our letter *w* may also be advantageously employed, instead of the single *u*, at the beginning of certain syllables which we should otherwise write with *oo*; for, if the combination *oo* should happen to precede or follow a single *o*, thus *oo-o* or *o-oo* (for *wo* or *ow*) it makes a very awkward and inconvenient orthography; and if the *oo* should precede or follow another combination of the same kind, thus *oo-oo* (for *wu*) the inconvenience is still more palpable. Our venerable *Eliot*, whose memory will ever be revered by scholars as well as by the friends of religion, both in his *Indian Grammar* and his *Translation of the Bible*, used a character composed of two *o*'s closely united thus (∞) resembling the figure 8 laid horizontally. This character answers extremely well; but as the simple *u* or *w* would always supply its place, and as both of these are familiar to the different nations of Europe, I have thought we might dispense with the character devised by Eliot. The Jesuit missionaries formerly taught their converts to denote this sound by the Greek character ȣ; and this is accordingly used throughout Father *Rale's* MS. Dictionary of the Norridgwock, or rather Abnaki, language, now preserved in the Library of our University in Cambridge. But, for the reasons before mentioned, I think that neither this nor Eliot's character will be found necessary.*

Such, I have observed, should be the *basis* of our Indian orthography. Any modifications of these fundamental sounds, which may be discovered in the different Indian languages, may be indicated by some diacritical marks placed above or below the letter which is employed to denote the fundamental or principal sound. For this purpose I should choose, if practicable, to adopt some other marks than the common signs of accent and quantity;

* See an account of this valuable MS. in the Appendix to the present paper.

because these signs have been so long employed to denote the usual, though vague distinctions of *grave, acute* and *circumflex* accents, and *long* and *short* syllables, that they would perpetually mislead readers of every nation; besides, it may be found useful to reserve them, to be placed over those syllables which in English we call *accented*, in order to denote that part of a word, upon which the greatest force, or stress of the voice falls in pronunciation.*

The elegant scholar, with whose remarks I have introduced this subject, and from whose well-considered opinions no man should dissent without great hesitation, after observing, that "our English alphabet and orthography are disgracefully and almost ridiculously imperfect," recommends, for the purpose of denoting modifications of this kind, the adoption of "some of the marks used in our treatises on fluxions;" and accordingly in his notation of Asiatick words, he makes use of either one, two, or three points placed over the letters, thus, $\dot{z}$, $\ddot{z}$, $\dddot{z}$.† This notation has the

* Eliot employed two of the accents in the following manner: "We use," says he, "onely two Accents, and but sometime. The *acute* (′) to shew which syllable is first *produced* in pronouncing of the word; which, if it be not attended to, no nation can understand their own language; as appeareth by the witty conceit of the *Tityre tu*'s: ó produced with the accent is a regular distinction betwixt the first and second persons plural of the Suppositive Mode; as

Naumog, if we see (as in *Log*)
Naumóg, if ye see (as in *Vogue.*)

The other accent is (^) which I call *nasal*; and it is used only upon (ô) when it is sounded in the nose, as oft it is; or upon (â) for the like cause." *Indian Grammar*, p. 3. These *nasal* sounds may be more conveniently designated in the manner adopted in the *Polish* language, which will be mentioned in a subsequent part of this paper.

† Dissertation, in Jones' Works, vol. i. p. 186.

manifest advantage of great simplicity; but on the other hand it should be considered, that these points are extremely subject to being wholly overlooked or confounded with each other both in writing and printing; and, in the science of mathematics, from which the learned author borrows them, it is a well known fact, that those treatises on fluxions, where this method is followed, abound in errors beyond all comparison more than those, in which the French notation by *letters* instead of points is adopted.* For this reason, therefore, marks of that kind should be used as sparingly as possible. We might, perhaps, conveniently enough designate the modified vowel by placing a small *letter* over it, as is done in the German language, where, for example, the vowel *a*, (which commonly has a sound like *ah* in English) if it has a small *e* over it (aͤ) takes a sound like *a* in fate; and the vowel *o* with a small *e* over it (oͤ) loses its usual sound and takes one resembling the French *eu*. It is true, that the Germans also use two points (thus ä, ö,) to denote these modifications; but these have been so long and so generally employed in ancient and modern languages as a *diæresis*, that it does not appear advisable now to apply them to a new use. If *points* are employed at all, it would be better to place them perpendicularly over the vowel (thus ȧ) and not horizontally. But perhaps the most intelligible and least ambiguous notation would be found upon experiment to be, such as is adopted in the pronouncing dictionaries of our own language, that is, the common numerals; instead, however, of placing them *over* the letter, as is there done, it will be better to place them *under* it; as the room above will be wanted for the

* The learned De Sacy observes, too, that in *Arabic* the ت (with two points) and the ث (with three) are often confounded in the Manuscripts. See his Arab. Gram. vol. i. p. 18—19.

accents and marks of *quantity*. But, whatever mode is adopted, an explanation should be given of it, by reference to one or more of the European languages, in a *Table* or *Key*, which ought, for the present at least, to accompany all publications in the Indian languages.*

There is, however, one class of sounds in some, if not in all the Indian dialects, I mean the *nasal* sounds, for which it seems absolutely necessary to introduce a new character; though it is always extremely desirable to avoid having recourse to this dangerous expedient in any alphabetic notation, which, like the present, is intended for a *practical* system. In those European languages with which we are most familiar, such nasal modifications are commonly denoted by subjoining certain consonants to the vowels thus modified; as *n* or *m* in the French language and some others; *ng* in the German and our own language. But nothing would be gained by adopting this method for the Indian

* In *Pryce's* Cornish Grammar and Vocabulary, published in the year 1790, a different expedient from any above proposed is resorted to; that is, turning the letters upside down. Thus, the vowel A in its natural position is sounded as in *man*, but when inverted (∀) it is to be sounded as in *fall*. This method, which does not seem to be a very eligible one, has been followed to a considerable extent in the TSVLVKI SQCLC CLV, or Cherokee Spelling Book, published by the Rev. Mr. Butrick, (the respectable missionary among the Cherokees) and his young assistant, Mr. D. Brown, who is one of that nation, and with whom I have had opportunities of conversing upon the subject of his language. I will here remark, by the way, as the name of this nation has been variously written, *Cherokee*, *Cheerakee*, *Chelokee*, &c. that Mr. Brown stated the true name to be, (as we should write it in English) *Tsuh-luh-kee'*, sounding the *u* as in *but* and throwing the accent upon the last syllable; and so it is to be pronounced according to the orthography used in the title of the Spelling Book above quoted. The corruption of *ts* into *tsh* (or our *ch*) is very common in the attempts to write Indian words.

languages, in which we have it in our power to establish a new notation that shall be *systematic*, so far as may be consistent with convenience in practice; because, if we apply those consonants, *n*, *m*, or any others, which already have certain established powers in the alphabet, to this new use of indicating nasal sounds, we shall then be obliged to affix to them a sign of some sort to point out when they do not indicate such sounds; or, in other words, to show when they retain what we now call their usual powers. In the *Polish* language these nasal vowels are designated by the little mark, called in some of the foreign languages a *cedilla*, which is placed under them thus, *ą ę į ǫ ų*; and Mr. Du Ponceau, to whom I am indebted for this and many other valuable suggestions, observes in a letter to me, that no other method has occurred to him, which would in practice be found so convenient as this for the proposed *Indian* alphabet; an opinion, in which every man, who has weighed the various difficulties in this case, will fully concur.* I will only add on this part of the subject, that it will be found best in practice to

* In printing-offices where types cannot at present be had for this purpose, the nasal vowel may be printed as it is in Volney's work, p. 59, with an inverted comma subjoined to it, thus, *a̦ e̦ i̦ o̦ u̦*. But as this may occasion a division of the syllables of a word (which should be avoided) new types ought to be made for the nasal vowels. In respect to the division of syllables I will here add a remark from one of Mr. Du Ponceau's letters to me: "The makers of Indian Vocabularies are in the habit of *dividing their syllables*, as in the Spelling Book. This is awkward and inconvenient, and will be useless on the principle of the new alphabet." This remark, occurring thus early, may require a short explanation. The method of *dividing* the syllables will become unnecessary, because in the proposed alphabet every letter is to have a fixed and invariable sound, however it may be combined with others; and in *spelling*, every syllable, except final ones, will end with a vowel.

place these, and any other distinctive marks of this sort, *under* the letters; because the room above, as I have before observed, will be wanted for the marks of accent and quantity.*

DIPHTHONGS.

The mode of writing the diphthongs, which would naturally follow that of the vowels, will need but a few remarks; for, as the diphthongs will be compounded of the several vowels whose powers have already been under consideration, and those writers

* Mr. Du Ponceau has suggested to me a method of indicating accent and quantity, in a manner which is at once simple and ingenious. He proposes, that *long* accented syllables should be marked with the *grave* accent, and *short* accented ones with the *acute*. "*Unaccented* syllables," he adds, "need no mark, being generally short." This method would be attended with no difficulty in the application, were it not for the different ideas, which different persons may affix to the terms *long* and *short* in this case. We say in English, for example, that *i* in the word *pine* is *long*, but that in *pin* it is *short*. This, to an Italian, French, or other foreign scholar, would be an absurdity; because it would be equivalent to saying, that the sound of our word *aye* and of our letter *e* (for so they would pronounce *i* in *pine* and *i* in *pin*) are the *long* and *short* of the same vocal sound; when too, as our own grammarians begin to admit, the letter *i* in the former case is a *diphthong*, and in the latter, a *vowel*. Yet, absurd as this appears, we see it carried into our methods of instruction in Latin and Greek, as well as in English. No person, however, who has given the least attention to those foreign languages, which are the most legitimate descendants from the Latin (that is, the Italian, Spanish and Portugueze) or in short, to any of the Continental languages of Europe, will suppose for a moment, that the distinction of *long* and *short* in the ancient languages was like the distinction which we make in English, in in the case of the *i* and some other vowels. But this is not the place for discussing a subject, which will more properly belong to a communication on the Accents of the Greek language, which I hope to make to the Academy on a future occasion.

of the Indian languages, who may adopt the proposed orthography of the vowels, will find no difficulty in combining these in such a manner as to constitute the required diphthongs. It may not, however, be without use to observe, that there are in some of the Indian dialects diphthongal sounds, which we are accustomed to denote in English by single letters. I have found, for example, and much to my surprise, by conversation with the young Cherokee mentioned in a preceding note, that in the language of that nation they have the diphthongal sound of the long *i* in our word *pine*, and of the long *u* in our word *pure;* both of which are at length admitted to be diphthongs by some of our own grammarians, as they have always been treated by the *Continental* nations of Europe, who generally denote the first of them by *ai* and the other by *iu* or *iou;* the sounds of which may be expressed in English by *ah-ee* and *ee-oo,* pronouncing the two parts of these words as closely together as possible.

To express these diphthongal sounds, therefore, which, like the vowels, will probably in some dialects be found to be more close, and in others more open, we cannot do better than to adopt the European *ai* and *iu;* to which we may add *yu*, to be used at the beginning of words, for the reasons which will be mentioned in considering the combinations *Li* and *Ly,* under the letter *L.*

We shall also want a character for the diphthong which we denote in English by *ou* in *our*, and *ow* in *now*. Either of our modes of writing this diphthong would be ambiguous to the people of Europe; for they would in general pronounce both of them like *oo* in English. Now those nations in their own languages would express this diphthong by *au* (except that the French would write it *aou);* and as this orthography would naturally follow from the sounds to be denoted by the two

component vowels *a* and *u*, there seems to be every reason, which practical convenience could suggest, for relinquishing our own *ou* and *ow*, and adopting *au* in common with those nations.

It need hardly be observed here, that if it should be found requisite in any Indian words, to mark very distinctly the separate powers of the two component letters in the *ai*, *iu* and *au*, and thus in effect dissolve the diphthong, it may be done by means of the common *diœresis.*

CONSONANTS.

B.

The letter *B* may have the power which it generally has in the European languages and in our own.

C.

The letter *C* may be entirely dispensed with, on account of its very changeable power in the European languages, and because its two most common sounds may be perfectly expressed by *K* and by *S*. Our venerable Eliot says of it—"We lay by the letter *C*, saving in *CH*, of which there is frequent use in the language."* But, for the *CH*, it will be found advisable that we should substitute another notation, which will be mentioned in its place under the letter *T*.

D; DH; DS *or* DZ; *and* DJ, DSH *or* DZH.

The letter *D*, when single, may have its usual power.

Dh may be conveniently used to denote what Walker calls in English the *flat* sound of *th;* that is, the sound which *th* has in

* Indian Gram. p. 2.

our words *this, that,* &c. and for which our Saxon ancestors had an appropriate character, but for want of which we should be obliged to write the same words, *dhis, dhat* &c.*

Ds or *Dz* will probably be wanted in some cases, to denote the *flat* sounds corresponding to *ts;* which last is very common in the Indian languages (though often corrupted into our *ch)* and is expressed by the *German* writers by a simple *Z;* a letter which in their own language, as is well known, has the power of *ts* or *tz* in English.

Dj, Dsh or *Dzh* may be employed to express the sound of our *J;* which, for the reasons that will be given under that letter, it seems necessary to reject from the proposed system of orthography.

* The *flat* sound of *th.* Nothing can be more unsettled and imperfect than our technical language in Grammar and Rhetoric; and this circumstance has much retarded the progress of accurate investigation in those two branches of our studies. So far as respects *sounds*, we cannot do better than to borrow terms from *Music,* which is the Science of sounds; and I have accordingly used the terms *flat* and *sharp* (or *grave* and *acute)* which I believe were first employed systematically in Walker's Pronouncing Dictionary, to designate the two classes of consonants often called mutes and semi-mutes, as *b, d, v,* and *p, t, f,* &c. Mr. Du Ponceau observes, that this distinction may be as good as any other; but he suggests, whether that of *inspirates* and *exspirates* would not be preferable; applying the former of these terms to the *flat* consonants, and the latter to the *sharp* ones; so that *B* will be called an *inspirate,* and *P,* an *exspirate,* &c. He is of opinion that "in pronouncing these two classes of letters, the organ in the one case expels the breath, and in the other draws it in.....The *exspiration,* in *t, th, f, p,* &c. (he remarks) is clearly and strongly to be perceived; the *inspiration* in their correlatives, perhaps not quite so much. To me it seems, that when you say *thunder,* you push the air out, when you say *that,* you draw or keep the air in as much as is possible in uttering a consonant."

F.

The letter *F,* whenever it shall be wanted, will have its usual power. But probably there will not be much use for it in many of the Indian dialects; for Mr. Heckewelder observes of the *Delaware* language, which is the basis of many others, that it has "no such consonants as the German *w*, or English *v*, *F*, or *r*."*

G, GH, GS.

The letter *G*, whatever vowel may happen to follow it, should invariably have the sound, which we call in English its *hard* sound; and which it generally has before *a*, *o* and *u*, in the European languages as well as our own. This power of *G* is commonly traced back no farther than the times of our Saxon ancestors; but scholars have supposed, and upon no slight grounds, that this was also its common sound, or a very near approximation to its common sound among the Romans, when it was followed by either of the vowels.

Gh may be used to denote the *flat* guttural of the Irish, which is the corresponding sound to the *sharp* guttural, or German *ch;* which last I should prefer designating by *kh*, as Sir William Jones recommends in the Oriental languages, and as will presently be more particularly considered under the letter *K*.

Gs will be wanted to denote the *flat* sound of *x*, in our word *example* and other words of that form, where the letter *X precedes the accented syllable;* as *ks* will be wanted to express the *sharp* sound which *x* has in our word *exercise* and in certain others which have the *X in the accented syllable.*

* Correspondence with Mr. Du Ponceau, p. 396. See also the *Note* on the letter *W* in the present communication.

H, HW.

H, either when single or in combination with others, may perform its usual office of an aspirate.

Hw will be wanted for the purpose of denoting the sound which in English we now express by *wh,* as in *what, when,* &c., though our Saxon ancestors used to put the *h* before the *w,* and wrote the same words *hwæt, hwænne.* The Swedes also (as Mr. Du Ponceau remarks in one of his letters to me) formerly used *hw* and *hu;* but at the present day, they as well as the Danes use *hv.*

J.

The use of the letter *J* is attended with more difficulty than any of the preceding consonants. A *German* or an *Italian* would inevitably give it the sound of our *y:** a *Frenchman* or a *Portugueze,* that of *zh* (or *s* in our word *pleasure;*) while a *Spaniard* would give it the strong guttural sound well known in his language. Under these circumstances, therefore, although it is extremely desirable to have *single letters* to represent *single sounds* (as we generally denominate them) yet it appears to me better on the whole to reject the letter *J,* and instead of it to adopt a combination of letters, which shall be in analogy with the common sound of our *ch (tsh),* which is the corresponding *sharp* sound to that of *J.* As, therefore, I shall presently propose to denote our *ch* by *tsh,* so in the present case I would supply the place of our *J,* by *dsh* or *dzh;* or, if it should be thought best, in a *practical* alphabet, to sacrifice analogy to simplicity, we might

* Mr. Heckewelder very judiciously employs the *y* instead of *j,* which Mr. Zeisberger and the other German Missionaries always make use of. *See his Correspondence with Mr. Du Ponceau,* p. 383.

express this sound by *dj* or *dg*, as the French commonly do in writing foreign words. In the *Malay* Bible and Testament, printed by the Dutch in 1733 (the latter of which was reprinted by the English in 1818) the Dutch have adopted a character compounded of *D* and *J* closely united thus, Dj, dj, which would be preferable to *dg;* but in that case, again, if we strictly regarded analogy, we should express *ch* by *tj*, as the Dutch have done in that work. This would be a little awkward to us and not free from ambiguity; as, for example, in the name of the place where the English edition of this Malay Testament was reprinted, and which is expressed conformably to the above notation thus, Tjàlsi, (to be sounded as if written *Tjelsi)* we should not immediately discover the plain English name, *Chelsea.*

In the case of this, as well as other letters of the alphabet, it will not be overlooked, that one advantage of having characters, which shall be in analogy with each other, is, that they will immediately point out to the eye many affinities, which under an irregular orthography are discoverable only by the ear; and, perhaps, in the present instance the character *dj*, which is less cumbrous than *dsh* or *dzh*, will sufficiently resemble *tsh* to answer that purpose.

K, KH, KS.

K, when single, may preserve its usual power, which is familiarly known to the European nations, though the letter itself is not used in all their alphabets.

Kh may be used to denote the *sharp* guttural, which the Germans express by *ch* and the Greeks by χ; while the corresponding *flat* guttural, as before observed, may be denoted by *gh.*

The combination *kh* is to be preferred to *ch*, because the latter would be ambiguous to Europeans in general, as well as to ourselves; for though the *Germans* would give *ch* the intended guttural sound, a *Frenchman* would pronounce it like our *sh*, and we should ourselves be in doubt whether to pronounce it like *tsh* or like *k*; while a *Spaniard* would give it the sound of *tsh*, and an *Italian*, the common unaspirated sound of *k*.

Ks will be necessary, to denote the *sharp* sound which *x* has in the word *exercise* and many others.

L; *and* LY *or* LI.

The letter *L*, whether single or double, may retain its usual power.

Ly or *Li* may be found useful, to express the *liquid* sound of *L*, as it is called, which is heard in the foreign words *seraglio*, *intaglio*, &c. and is observable in our English word *steelyard* and some others; which, if we divide thus, *stee-lyard*, the last syllable will give us this common foreign sound with the greatest exactness. The French express the same sound by *ll* after *i*; the Italians, by *gl* before *i*; the Spaniards, by *ll*, and the Portugueze, by *lh*. But either *ly* or *li* will, I think, be attended with fewer difficulties in practice, than any of the combinations above mentioned, in a system of orthography which is to be used in common by several European nations and ourselves; and of these two, *li* and *ly*, we should ourselves in most cases, especially at the beginning of a word, give the preference to *ly*; though to foreigners, it would be a matter of indifference which of them should be adopted. It may be thought indeed, that there is no necessity for both of them; and, strictly speaking, perhaps, there is not any more than there is for retaining both of

the single letters, *i* and *y*, among the vowels and diphthongs. Yet we have ourselves been so much accustomed to the use of *y*, instead of *i*, before the other vowels, and particularly in the beginning of words and before the letter *i* itself, (where we could not without doing great violence to our habits employ the *i*,) that it seems advisable to retain *i* and *y*, and for the like reasons, the *li* and *ly*. This will also be in conformity with the actual practice of the German missionaries, who use both their *i* and their *j* (which last is equivalent to our *y*) in writing Indian words.*

M.

The letter *M* will have its usual power, which is, practically speaking, the same in the European languages in general.†

* Perhaps it will not be found necessary to adopt any character to express the *liquid l* (or *l mouillée*;) for Mr. Du Ponceau informs me, that he has not yet met with this sound in any of the Indian languages examined by him. I once thought of using the Spanish *ll* for this sound; but upon Mr. Du Ponceau's suggestion, that there might in some Indian words be occasion to express a full and distinct sound of two *l*'s following each other, as in the Italian words, *bel-la*, *stel-la*, I abandoned it. In our own language we are not in general sensible of any difference between two *l*'s and one; but if we take a word in which the second *l* is under the accent, as in *illegal*, *illustrate*, &c. or if we pronounce two words together, the first of which ends, and the second begins, with *l*, as in *full length*, *well looking*, &c. the difference becomes more perceptible.

† The Portugueze final *m* and the French *m* and *n*, which are nasal (or the signs of a nasal sound in the vowel annexed to them) need not, in this general view, be considered as exceptions.

N; *and* NY *or* NI.

N may also retain its usual power, which (as was observed in the case of *M)* is the same in the European languages generally.*

Ny or *ni* may be wanted to express the sound of *gn* in the foreign words *bagnio, seignior,* and which we hear in our words *convenient, minion, whinyard,* the proper name *Bunyan,* &c. The Spaniards, as is well known, have an appropriate letter for it in their alphabet, being an *n* with a mark over it, thus, *ñ;* the Portugueze denote it by *nh,* and the Italians by *gn.* But for similar reasons to those mentioned in the case of the *ly,* I think we shall find *ny* more convenient in practice than either of these.†

P.

The letter *P* may have its usual power.

Q.

This letter may be entirely dispensed with; as its place may be perfectly supplied by *K.* Some writers have used *Q* alone in writing Indian words to express the sound of *qu* or *qw;* but *kw* would, I think, be far preferable in every point of view. If the *Q* is preserved in any Indian alphabet, it may be applied to designate some uncommon modification of its usual sound; and such modification should be indicated by some mark affixed to the letter.

* See note † on the preceding page.

† Mr. Du Ponceau tells me that this *liquid n* (or *ny)* is found in the *Caribbee* language.

R.

R may preserve its common sound, which is fundamentally the same in the European languages, though uttered with very different degrees of force, or roughness, by different nations.

S, SH.

S should always have its common sibilant power, and never be pronounced like *Z*.

Sh will be wanted, and appears to me preferable to the combinations of letters now used by some European nations, to denote that sound which we always express by *sh*, and which is common to our own and many other languages in various parts of the globe. The *French* express it by *ch*, which we have retained in the word *chaise*, and others borrowed from them. But the use of *ch*, in the Indian languages, would mislead readers of different nations; for a *German* would pronounce it as a guttural (like *kh*), an *Italian* like *k*, a *Spaniard* like *tsh*, &c. The Germans denote this sound of our *sh* by *sch*; which combination, besides being incumbered with one more letter than our *sh*, would indubitably mislead an Italian, and an Englishman, and perhaps readers of some other nations; for an Italian and an Englishman would pronounce *sch* like *sk* instead of *sh*. It is, doubtless, in consequence of this ambiguity in the *sch*, that we so often hear the name of that northern region, which is commonly written *Kamtschatka*, corruptly pronounced *Kam-skatka*, instead of *Kam-tchatka*, (or *Kams-tchatka*, as we ought to call it, if we wish to come as near to the Russian pronunciation as our organs will permit, without an unnatural effort;) for, as we borrow the orthography of this name from the *Germans*, through whose works we principally derive our information of that

country and who write it *Kamtschatka,* (with *sch*) we naturally pronounce the letters *sch* like *sk,* according to the general analogy of our own language.* Our *sh,* then, being more simple in itself than the German *sch,* yet sufficiently near to that as well as to the French *ch,* to indicate its power in most cases, and being also an unusual combination in the European languages, would be free from the ambiguity attending the German *sch,* and not so likely to mislead readers of different nations.

The corresponding *flat* sound to *sh,* that is, our *s* in the word *pleasure* (or *j* in French,) may be denoted by *zh,* as will be noticed under the letter Z.†

T; TH; TS *and* TZ; TSH.

The letter *T,* when single, will have its common power. It will also be used in the three following combinations:

The first of them, *th,* is always called in foreign grammars the *English TH,* and is now well understood and used by the nations of Europe, when they wish to express that sharp lisping sound which it has in our word *thin, thick,* &c. and which is

* This name in the Russian language (as Mr. Du Ponceau observes) is written Камщатка, the fourth letter of which is equivalent to *shtsh* in English. We ought, therefore, in strictness to write and pronounce it *Kamshtshatka*; which, if we follow the Russian letters, would in spelling be divided thus, *Kam-shtshatka*; but to make it more intelligible in English, we might write and divide thus, *Kamsh-chatka.* In our pronunciation, however, this is generally softened either into *Kams-tshatka,* or *Kam-tshatka.*

† There would be a convenience in having these compounded characters, *sh, zh* and others, printed in one character, as our *sh* always used to be; and if new types are made, it may be well to attend to this point. In our own and other languages, however, no great inconvenience is felt from the use of separate letters.

supposed to have been the ancient, as it is the modern, sound of the Greek *theta*. The corresponding *flat* sound (which is heard in our words, *this, that*, &c.) should be expressed by *dh*, as I have observed under the letter *D*.

The second is *ts;* which, being formed of two letters whose powers may be called invariable, will never be ambiguous. This will be much preferable to the German *Z*, which has the power of *ts* or *tz*, but which most nations would pronounce in their own languages as we do in ours, and would therefore be misled in the pronunciation of Indian words, where this letter occurs. Thus, for example, if a Frenchman and an Englishman should happen to meet with the expression in the Delaware language, which a German would write *n'mizi* (I eat) the former of them would pronounce it *n'meezee*, and the other, *n'mizi*, (sounding the *i* as in *pine*,) both of which would be unintelligible to an Indian of that tribe; while the German alone would pronounce it correctly, as we should write it in our English manner, *n'meetsee*.

I have here spoken only of *ts* as a substitute for the German *z;* but *tz* may perhaps be required to express a slight modification of this fundamental sound, which may probably be observed in some particular dialects, or in different words of the same dialect. The acquisition of this and numberless other delicate distinctions of fundamental sounds, which may be perceived in the various Indian dialects, and the establishing of distinct characters for them, must, if practicable at all, be the result of long and careful observation on the part of those, who may be called to reside among the different tribes.

The remaining combination, *tsh*, may be employed to denote the sound of our *ch* (in *chair, chain*, &c.) which the French

would expresss by *tch* and the Germans by *tsch*. It would be desirable, it is true, to have a character of greater simplicity than these three letters make, and on that account our *ch* would be preferable to *tsh*; but for the reasons before given (under *kh*) it would not be expedient to adopt it. The Russians in their copious alphabet are fortunate in having a single character to denote this sound, as we have in our *J*, for the corresponding *flat* one; they would express our *ch* by Ч, which resembles our *h* inverted; and if there was as much literary intercourse with the Russians, as with the Germans and other people of Europe, and the rest of the proposed alphabet was common to them and other nations, it might be found advisable to add to it this very useful Russian character.

V.

The letter *V*, whenever it shall be wanted, will have the usual power. But probably there will not be much use for it in many of the Indian dialects, for the reasons given under the letter *F*.

W.

This letter has been already considered in the remarks upon the vowels, at page 330.*

* In the *Delaware* language, (as the Rev. Mr. Heckewelder observes,) where the letter *W* " is placed before a vowel, it sounds the same as in English; before a consonant it represents a *whistled* sound, of which I cannot well give you an idea on paper, &c. *See his Correspondence with Mr. Du Ponceau*, p. 396.

Mr. Du Ponceau, in a letter to me, says upon this point—" I have analysed the whistling *W* of the Delawares. It is nothing more than our *oo* consonant, *w* or *wh*, in *well, what*. The Delawares pronounce it immediately before a consonant without an intervening vowel; which habit enables them to do, while

X.

X is altogether unnecessary, as its two common powers may be expressed by *ks* and *gs ;* and if the *x* itself should be adopted, it would be quite uncertain, both to ourselves and to readers of some other nations, which of the two sounds here mentioned was intended by it; besides which, a Spaniard would be in doubt whether to give it the first of the two sounds here mentioned, or the guttural one which the *x* has in his own language; while a Portugueze would pronounce it like our *sh,* which is its common power in his alphabet.

Y.

For the use of this letter, see the remarks upon the vowels, at page 329.

Z, ZH.

The letter *Z,* when single, will have the power it has in *French, English* and some other languages. In this case, however, it will be necessary for the Germans and Italians to relinquish their peculiar pronunciation of it, and to adopt the substitutes proposed in the preceding remarks; that is, *ts, tz, ds* or *dz,* as the case may be found to require in the different dialects.

Zh will serve to designate the corresponding *flat* sound to *sh ;* that is, the sound of the French *J,* which is equivalent to our *s* in the word *pleasure.*

we cannot, unless practice has made it familiar to us; as it has to me. Take the word *wet,* you pronounce it easily; transpose the vowel and write it *wte,* a Delaware will pronounce it with the same ease; when we cannot. Try a Frenchman at pronouncing this hemistich out of Paradise Lost—*Heav'n's last best gift ;* he will be as much embarrassed with the *vnsl,* the *stb,* and the *stg,* (which habit makes us pronounce with great rapidity and ease) as we are with the *wt* of the Delawares."

The whole Alphabet, then, of the proposed systematic Orthography, that is, the *basis* or *fundamental characters* of it, will be as represented in the following *Table;* in which the several characters are arranged according to our common alphabetical order, without any attempt being made to class the *sounds* according to their organic formation; because, useful and necessary as this would be in a philosophical investigation of the affinities of those sounds, it would not be attended with any important advantage in an alphabet, like the present, designed merely for practical use. When we are searching for a word in a dictionary, whether of the Indian or any other language, we naturally look for the *written sign* in the place where it ought to stand according to the arrangement of our own alphabet.

I may here add, what I wish to be distinctly understood, that, as it never was my plan to give a *universal* alphabet on strict philosophical principles for the use of the learned, but merely a *practical* one, to be applied to the Indian languages of North America, so I have intentionally omitted many sounds, which occur in the languages of Europe and other parts of the world, and numerous modifications of greater or less delicacy in some of the fundamental sounds which have come under my notice. Among such omitted sounds might be mentioned the various slight differences (to an unpractised ear often imperceptible) in the French *e* and other vowels, depending upon the accent affixed to them, and about which, indeed, their own writers have differed, as our own do in respect to the nicer distinctions of English pronunciation—the French *u* (German *ü*, Danish and Swedish *y)*—the French *eu* or *oeu* (German and Swedish ᵒ̊ or ö, Danish ø) &c.; to which might be added the Polish *l barrée* ł or crossed *l)* which, as Mr. Du Ponceau remarks, is found in

the *Caribbee* language, and to pronounce which we must place the tongue as far back as possible on the roof of the mouth and articulate *l*. But to have overcharged the proposed alphabet with a great many niceties of this kind, (if it had been in my power to represent them all with exactness) would have had a tendency to frustrate the very object I had in view; that is, a *practical* system of orthography. In such a system, an *approximation* is all that we can expect, and perhaps all that is at present necessary in our inquiries. If the alphabet here given shall prove to be sufficiently well adapted to the purpose of denoting what may be called *fundamental* sounds of the principal Indian languages, it will not be difficult hereafter, gradually to make provision for such signs as experience may suggest, in order to designate all the delicate modifications of speech, which the nicest ear shall be able to discover in the different dialects. But *new signs* should be introduced with the greatest caution, lest we should have an alphabet, which will be too cumbrous for use in writing, and will require a multitude of new types for printing, these languages. The great danger will be (as Mr. Du Ponceau has observed to me) that every man, however little qualified, "will think himself adequate to the task of inventing new characters, and will delight to display himself in that way. These displays are used in order to conceal the want of ideas and resources." As in the use of our own language, it is much easier for every tasteless writer to invent new words according to his own caprice, in order to serve his immediate purposes, than patiently and carefully to select from our present abundant stock those appropriate terms, which have the sanction of the best usage; so, in constructing an alphabet for the Indian languages, it will be found a much shorter method, to devise new and gro-

tesque characters, than to apply with skill and discrimination those letters which are already in use either in our own or the kindred alphabets.

I once thought of adding to the proposed alphabet appropriate *names* for the letters; but as this was not strictly within my original plan, and would only be necessary in the instruction of pupils, I relinquished it. The names in common use among the European nations and ourselves will answer sufficiently well, with the exception, perhaps, of such as our *G*, *H*, *W*, and *Y*; which might be called by names, that would more immediately suggest to the learner the respective powers of those letters, than is done by their present denominations; thus the letter *G* instead of being called *jee*, might have the name of *ghee*, which *Eliot* used to give it;* *H* might take the German appellation *ha* or *hau*; *W* might be called *wee*,† as Eliot also named it; and *Y* might be called *ye* or *ya*. Perhaps, too, some suitable appellations may be wanted for the compound characters *sh*, *tsh*, &c. to give the learner some idea of their powers. But, for the reasons above mentioned, it is not necessary here to enter upon the consideration of this subject.

I now subjoin in one view the proposed *Indian Alphabet*, in the following Table; in which, the first List contains the common letters of our alphabet, as far as it seems practicable to adopt them; the next contains the class of *nasals*; after these follow the *diphthongs*; and lastly, a number of *compound characters*, which will be of more or less frequent use in different dialects.

* Indian Gram. p. 3.

† "We call *W* (*wee*) because our name giveth no hint of the power of its sound." Indian Gram. p. 2.

TABLE OF THE ALPHABET.

A as in the English words, *far, father*, &c. (But see the *Note on the Vowels*, p. 355.)
B as in English, French, &c.
D *(the same.)*
E as in the English word *there;* and also short *e*, as in *met*, &c.
F as in English, &c.
G English *g* hard, as in *game, gone*, &c.
H an aspiration, as in English, &c.
I as in *marine, machine*, (or English *ee*); and also short *i* in *him*.
K as in English.
L *(the same.)*
M *(the same.)*
N *(the same.)*
O English long *o*, as in *robe;* and also the *o* in *some, among, above*, &c. which is equivalent to the English short *u* in *rub, tun*, &c. (But see the remarks on this letter, p. 357.)
P as in English, &c.
R *(the same.)*
S as in English at the beginning of a word.
T as in English, &c.
U English *oo*, both long and short; French *ou*.
V English *v*, German *w*, Russian *b*, Modern Greek *β*.
W as in English; French *ou*.
Y as in the English words, *yet, you*, &c.
Z as in English, &c.

NASALS.

A̧ as in *ang* (sounding the *a* itself, as in *father.*) But for a better description of this and the other nasals, see the *Note on the Nasals*, p. 357.
Ȩ *long*, as in *eyng* (pronouncing the *ey* as in *they;*) and *short*, as in the word *ginseng;* Portuguese *em* final. (See *Note on the Nasals*, p. 357.)
I̧ *long*, as in *eeng;* and *short* as in *ing;* Portuguese *im* final. (See *Note on the Nasals*, p. 357.)
O̧ *long*, as in *owng* (sounding the *ow* as in *own;*) French *on;* Portuguese *om* final. This character will also be used for *o* short *nasalised*, which is very nearly the same with *ong* in *among*, as this latter is equivalent to *ung* in *lung*, &c. See *Walker's Dict. Principles, No.* 165. See also the *Notes on the vowel O, and on the Nasals*, p. 356, 357.
U̧ as in *oong;* Portuguese *um* final.

To these should be added a character for the nasal *awng* or *ong* which corresponds to our *o* in *for, nor*, &c. And, as I have proposed (in p. 356,) to denote this vocal sound, when not *nasalised*, by *aw*, so it would be most strictly conformable to my plan, to denote the same vocal sound, when it *is nasalised*, by *a̧w̧* or *a̧w*. But perhaps the letter *a* itself, with the cedilla (*a̧*) may be used without inconvenience for this broad nasal sound, and we may still, in the common vowels, reserve the simple *a* to denote the sound it has in the word *father*, and not the sound of *aw*. For it may be found, that the first nasal sound in this Table is not common in the Indian languages; in which case it would be best to use the simple *a̧* for the broad nasal here mentioned.

TABLE OF THE ALPHABET CONTINUED.

DIPHTHONGS.

AI English *i* in *pine.*

AU English *ow* in *how, now,* &c. and *ou* in *our.*

IU English *u* in *pure ;* French *iou.*

YU to be used at the beginning, as *iu* may be in the middle, of words.

ADDITIONAL CONSONANTS.

DJ, DSH, or DZH, English *j* and *dg*, in *judge ;* French *dg.*

DH, as in the English words, *this, that ;* the δ of the Modern Greeks.

DS, DZ ; TS, TZ, English *ts* in the proper name *Betsy ;* German and Italian *z ;* German *c* before the vowels *e* and *i ;* Polish *c* before all the vowels ; Russian *Tsi.* These four compounds being nearly alike (as Mr. Du Ponceau justly observes to me) the ear of the writer must direct him which to use, as the respective consonants predominate.

GH, See *kh* below.

GZ, or GS, English *x* in *example, exact.*

HW, English *wh* in *what, when.*

KH, guttural, like the Greek χ ; Spanish *x, g,* and *j ;* German *ch ;* Dutch *gh.* I have in the preceding paper given the preference to *kh* for the purpose of expressing this guttural sound ; but *gh* pronounced as the Irish do in their name *Drogheda,* &c. may be better in certain cases where this guttural partakes more of the flat sound, *g*, than of the sharp one, *k*. It may be observed, that *gh* has been already used in some of the books printed for the use of the Indians.

KS, English *x* in *maxim, exercise.*

KSH, ——— *xi* in *complexion ; xu* in *luxury.* The formation of this combination would be obvious ; but as the sound is actually often used in the Delaware language, I have thought it best to notice it.

KW English *qu.*

LY or LI, as in the English word *steelyard ;* French *l mouillée,* Spanish *ll*, Portuguese *lh*, Italian *gl* before *i.*

NY or NI, as in the English proper name *Bunyan,* and the words *onion, opinion,* &c.

TH, in the English word *thin ;* Greek ϑ.

TS, TZ, See *ds* above.

TSH, English *ch,* in *chair ;* Spanish *ch* in *much ;* Italian *c* before *e* and *i ;* German *tsch ;* Russian ч.

WT, as in the Delaware language.

ZH, as s in *pleasure ;* French and Portuguese *j ;* Polish *z*, with a comma over it (ż).

NOTE ON THE VOWELS.

In considering the several *letters* by which the vowel *sounds* are represented, both in our own and other languages, it will be perceived, that each of them may be taken as representing, not a single sound, but a *series* of sounds, which series will be more or less extensive according to the genius of different languages; and it will be further observed, that each series gradually runs into the adjoining series (if we may so speak) by such slight and delicate modifications, that it is a matter of no small difficulty, in many cases, to decide in what part of any one series we should drop the vowel character with which we begin, and take another to continue the sounds of the next series; in other words, it is not easy to determine, at what point one series ends and another begins. For example; if we take the letter *a*, we may assume the sound which it has in the word *father*, as the middle point of a series, the whole of which, (beginning with the broad *a* in *fall* and ending with the narrow or slender *a* in *fate*) we denote in English by this one character, thus: fAll—fAr—fAt—fAte—
and these are all the sounds in this series, which philologists designate in our own language by this one letter. But if we extend our view to other languages, we shall find various intermediate sounds between the two extremes of this same series; for example, between the sounds of our *a* in *fall* and in *far*, we find in the *French* language, the *â* in *pâle*, *mâle*, &c. which can only be described, on paper, as a sound between our two, and which is seldom attended to by foreigners in speaking French. Now, if we should minutely examine a number of languages, and should endeavour to arrange accurately in one progression all the vowel sounds belonging to this series, we should doubtless discover in those languages many other slight modifications intervening between the different members of our English series. As, however, we cannot accustom our ears familiarly to distinguish, nor our organs of speech to utter with precision, all these slightly differing sounds, so we need no distinctive characters to represent them to the eye, but it will be sufficient in practice to have characters for the *principal* sounds (as we may call them) in each series; just as in the prismatic series of colours, we content ourselves with a few names to denote one principal shade of each colour, without fruitlessly attempting to devise terms of theoretical nicety, to describe the innumerable shades on either side of the principal one from which we set out.

If we now recur for a moment to the series above denoted by *A*, we find on one side of it a series which we denote by the letter *O*, and on the other side, a series which we denote by the letter *E*; in the former we begin with the sound of *o* in *morn*, which might be written with *au* or *aw* (or with *a* alone, if we had been accustomed to write this word with that letter, as we do the word *war*) and then we proceed to the sound which it has in *more*, till we arrive at that which it has in *move*; which point may be considered, practically speaking, as forming the end of one series and the beginning of another, which is represented by the letter *U*; and these two contiguous extremes are sometimes represented by *o* and sometimes by *u*, that is, our *oo*. If we now take the other side of the series, represented as above by *A*, and set out from the sound which that letter has in the word *fate*, we enter upon a series, of which the letter *E* may be called the representative, beginning with its sound in the word *met*, which is the short sound of *a* in *fate*; and this series, proceeding imperceptibly through various gradations, at length vanishes in the simple unequivocal sound of *ee*, which foreign nations denote by the third vowel, *i*. The following table will perhaps make these remarks more intelligible:

Series of the letter A:

fAr
fAll fAt fAte
mOrn thEre

Series of O: *Series of* E:

mOrn thEre
mOre thEse
mOve marIne, &c.
rUle, &c.

Now in writing the Indian languages, it will often be found extremely difficult to decide in each series of the vowel sounds, to what extent on each side of the principal or middle point (as I have called it) we shall use the same vowel character, or when we shall have recourse to the letter which is the representative of the next adjacent series.

From these considerations in the case of the vowel *A*, though we have no difficulty in using it to denote the sound of *a* in *far*, yet when we proceed in the series to the full broad sound which it has in *fall*, we feel a repugnance (arising from old habits in our own language) to denoting that sound by the single vowel, and are rather inclined to express it by *au* or *aw*. If it should be thought that it might be denoted by *o* (as in *for*) it will be obvious, that this would only be throwing the same difficulty into another series, and we should then have to decide again, how far the letter *o* shall be employed in that series, on each side of its principal sound of *o* in *more*. Now this broad sound (*aw*) though found in the European languages, is not commonly represented in them by the letter *A*; and therefore foreigners, who should attempt to read any Indian language, in which the simple *a* was employed to denote the sound *aw*, would inevitably be misled, and pronounce the *a* in *father*. It has therefore seemed to me better, in an alphabet designed for general use, to employ *aw* to denote this broad sound, and to reserve the single letter *a* to denote its common foreign sound, as in *father*. I should use *aw* and not *au*, because the latter has already the established power of a *diphthong* in the foreign languages, equivalent to our diphthong *ow* in *now*, *how*, &c. but *aw*, being a combination not in common use, would attract the attention of the foreign reader as a new character, and would not lead him into error. Mr. Du Ponceau, after much reflection, prefers using *a* alone for the sound of *aw*, and then denoting the sound of *a* in *father* by the diphthong *æ*. His opinion much diminishes the confidence I have had in my own; but as my plan was founded upon the idea of taking the *common* European sounds of the vowels as the *basis* of the alphabet, I have thought it would be too great a departure from it, if I should give to the vowel *a* any other than such common sound.

It will be observed, that I have employed the letter *O* as the representative of two sounds; that is, the *long* sound of *o* in *robe*, *tone*, &c. and the *short* sound of *u* (as we term it in English) in *rub*, *tun*, &c.; which latter sound, as appears in the Table, we often denote in English by *o* also; as in the words *among*, *above*, &c. In conformity with this use of the simple character *o*, I have, in the Table of *Nasals*, employed the same letter also with a cedilla (ǫ) to denote both the *long* nasal *owng* (French *on*) and the *short* nasal which we hear in *among*, *hunger*, &c. Those persons, who have not had occasion to analyze the sounds of our language and to remark how often we represent the same sounds by different characters, and *vice versâ*, are not aware how apt the ear is to be misled by the eye; or, in other words, how apt we are to judge of vocal sounds by the written characters which we are accustomed to employ in representing them; and such persons may, perhaps, from the force of habit, feel a little repugnance to denoting by the single letter *O*, two sounds which, in our own language, we have been used to consider as essentially different from each other and to express, in general, by the two different characters *o* and *u*. A careful comparison, however, of these two vowel sounds, under various combinations of the consonants, will show that they do not differ so materially as our various modes of representing them might lead us to suppose; but on the contrary, that their principal difference is in their length or *quantity*; while in respect to *quality*, the difference between them (to apply the language of another science) may be almost said to be less than any assignable one, and therefore they may well enough be denoted by the same letter. In addition to the proof we have of this close resemblance, from an examination of our own language, we see also very strong evidence of it in the case of *foreigners* when attempting to speak our language; for they constantly express our short *u* by *o*; as for example, in our word *but*, which they would write *bot*, and would pronounce *bote*. If, however, any person, who may

wish to adopt the proposed Indian alphabet, should still feel a reluctance in employing the letter *o* (even with a distinctive mark as mentioned in pp. 330—33[illegible]) for the purpose of denoting this short sound of *u*, I know of no method of obviating the difficulty (consistently with the plan of the alphabet) except by having recourse to a *new character*; and in that case I have thought that it might be formed from the same letter *o*, by making a small opening in the upper part of it in this manner, Ʊ. This character would sufficiently resemble both *o* and *u* to be easily retained in the memory, and would, moreover, occasion no embarrassment in printing the Indian languages; for those printers, who may not be provided with types expressly made for the purpose, might easily form this character out of a common type, by merely cutting out a small portion of an *o* (thus, *ʊ*) which would answer the purpose. The only objection to this would be the general one, the inconvenience of multiplying new characters; upon which point I have made some remarks in page 351 of this Essay. For further remaks on the subject of the letter *O* see *Walker's Dictionary*, *Principles*, No. 67 and 165.

The Nasals. The description of the *Nasals*, in the preceding *Table*, by the syllables *ang*, *eeng*, &c. is to be considered merely as a rude approximation to their true sounds. Those persons who are acquainted with the French language will need no description of them; those who are not, may possibly have a more just conception of them by carefully attending to a class of English words, in which the *nasal* is followed by the consonants *g*, or *k*, or c hard; as in *linger*, *thinking*, *uncle*, &c. If we divide one of these words a little differently from our usual method of spelling them, the true nasal sound will become distinctly perceptible. The word *linger*, for example, is usually divided into two syllables, the sounds of which we should express separately, thus *ling-ger*; now in pronouncing the word in that manner, as soon as we arrive at the end of the first syllable, the tongue is perceived to touch the roof of the mouth. and we then distinctly hear the sound of our English *ng*: But if, instead of thus fully pronouncing the whole of the syllable, we prolong the indistinct sound which is formed the moment before the *g* is uttered, and do not allow the tongue to touch the roof of the mouth, we shall have the *short* nasal sound *i̧* in the Table; and if we go through the same process again, only giving the vowel *i* its long foreign sound (like our *ee*) we shall have the *long* nasal sound of the same character *i̧*. And in a similar manner we may form the other nasal sounds in the *Table*. For further observations on the *nasal* sounds, see *Walker's Dictionary*, under the word *Encore*, and also his *Principles*, No. 381 and 408.

In connexion with the subject of the nasals it will not be uninteresting to refer to a curious remark of an ancient writer upon the subject of the letter *N* before *G* or *C*, in the *Latin* language. The remark is to be found in *Aulus Gellius* (lib. xix. c. 14.) who cites it from *Nigidius*; and it shows very clearly the Roman pronunciation of the letters *ng* together, while at the same time it indicates, that the letter c (being pronounced like *k*) when preceded by *n* coalesces with the *n* just as *g* does; as is the case with c hard in many English words:—"Inter literam *N* et *G* est alia vis; ut in nomine *anguis* et *angaria* et *ancoræ* et *increpat*, et *incurrit* et *ingenuus*. In omnibus enim his, non *verum N*, sed *adulterinum* ponitur; nam *N* non esse lingua indicio est; nam, si ea litera esset, *lingua palatum tangeret*."

CORRECTION.

After the 345th and 346th pages were printed, Mr. Du Ponceau expressed some doubts respecting the Russian orthography of the word *Kamtshatka*, which he gave me from recollection only; and I now find, upon inquiry of a Russian gentleman in Boston, that the name is written in that language Камчатка, which would be in English *Kamchatka* or *Kamtshatka*.

APPENDIX.

Account of Father Râle's MS. Indian Dictionary.

I have thought it would not be uninteresting, and might be of some use, to give in this place a short bibliographical account of the valuable Manuscript Dictionary of the *Abnaki* language mentioned in p. 330 of the preceding paper. The author of it, Father *Sebastian Râle* (or *Rasles*, for the name is written both ways) was one of the Jesuit Missionaries, and came to New England in the year 1689. He resided with the Indians principally at a settlement called *Norridgwock* (which he calls *Nanrantsouak*) on the river *Kennebeck*, upwards of thirty years, and was killed in a battle between the Indians and English in 1724. A short but interesting memoir of this able missionary was lately published by the Rev. Thaddeus M. Harris, D.D. in the Massachusetts Historical Collections, vol. viii. Second Series, p. 250. In the same volume will be found copies of some of his letters, with other papers respecting him, which I transcribed from the originals deposited in the archives of Massachusetts; among them is a very spirited manifesto, in *French*, from various tribes of Eastern Indians against the Provincial Government of Massachusetts, probably written by *Râle* himself. Other letters of his, and an account of his death, will be found in that valuable work, well known among the learned, under the title of *Lettres Edifiantes et Curieuses* (published in 26 volumes, 12mo.) which contains Letters or Reports of the Jesuit Missionaries in various parts of the world: *See vol.* vi. p. 127.

The MS. is a quarto volume and in the hand-writing of *Râle* himself. On the first leaf is the following note:

"1691. Il y a un an que je suis parmi les sauvages, je commence a mettre en ordre en forme de dictionaire les mots que j'apprens." Immediately below this there is, in an old hand-writing, the following:

"Taken after the fight at Norridgwock among Father Ralle's Papers, and given by the late Col. Heath to Elisha Cooke, Esq.

Dictionary of the Norridgewalk Language."

The volume consists of two parts, the *first* of which is a *general Dictionary* of the language in French and Indian. This part consists of 205 leaves (as they are numbered) about one quarter part of which have writing upon both sides, and the remainder, upon one side only. The pages are divided, though not with regularity throughout, into two columns; the first of French, and the second of Indian, containing each about twenty five lines. The *second part* of the volume consists of twenty five leaves, almost all written upon both sides, and has this Latin title—"*Particulæ.*" In this part the *Indian* words are placed first, and the author gives an account of the *particles*, making his explanations sometimes in French and sometimes in Latin.

From a comparison which I have made of several words of the language now spoken by the *Penobscot* Indians (as we call them) who, at the present time, occupy a small territory on the river Penobscot, it appears to be, as we should naturally expect, exactly the same with that of *Râle's* Dictionary. A few years ago one page of this Dictionary, containing the Indian numerals, was published in our Massachusetts Historical Collections, vol. x. p. 137; but a very natural mistake, either of the printer or of the transcriber, runs through this extract, in constantly printing *aü* instead of *aṅ*. This error probably arose from the uncommon use of the diæresis, which is here put over a consonant (N) instead of a vowel, as is the practice in other languages. *Râle* seems to have used the diæresis thus, in order to point out when the letters *an* were not to have the nasal sound which they had in the French language.

So copious a dictionary, compiled a century ago by a man of acknowledged abilities and learning, and who had resided more than thirty years among the Indians, is one of the most important documents now existing, relative to the history of the North American languages; and measures ought to be taken without loss of time, either under the direction of the University or of the American Academy, to effect the publication of it, before any accident happens to the manuscript. The Legislature of our own State would, without doubt, be fully sensible of the importance of publishing it, and would lend its aid in making provision for the expense of printing in a manner becoming the Government, a work which

the public has a peculiar right to expect from the State of Massachusetts. Our brethren in Pennsylvania have recently distinguished themselves by their valuable publications relative to the Indians, which I have mentioned in the preceding paper, and which may be said to form an era in our *American Researches.* It is to be hoped that our own State, which may justly claim the merit of having already preserved many invaluable materials for American history, will not be willing to let pass an opportunity, like the present, of adding to its reputation abroad by publishing the work in question; for we may be assured, that nothing would reflect more honour upon the country, and nothing relative to this continent would be more acceptable to Europeans, particularly the German literati, than the publication of such an original document.

POSTSCRIPT.

Page 322. " *The first fruits of these inquiries,*" &c.

I have unintentionally overlooked the useful work of the late Dr. *Barton*, entitled "*New Views of the Indian Tribes,*" &c. of which two editions have been already published, and which it was the author's intention to have rendered still more valuable by an entire revision of it.

XXIII.

Observations made with Fahrenheit's thermometer, at Salem, Mass. from the year 1793 to the year 1818, both inclusive, being the last 26 years of a period of 33 years' observations, the first series of seven years of which was published in the Memoirs of the American Academy, in the year 1793.

By EDWARD AUGUSTUS HOLYOKE, M. D.

PRESIDENT OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES.

Computed by Elisha Clap, F. A. A. and communicated by Levi Hedge, F. A. A. Professor of Logick and Metaphysicks in Harvard University.

1793. Second Series.

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P. M.	Mean.
Jan.	25.16	32.38	28.8	25.38	27.93
Feb.	26.75	33.67	30.42	26.78	29.405
Mar.	36.03	44.58	39.12	34.93	38.66
April	49.66	56.86	48.65	43.57	49.685
May	62.96	71.32	60.55	55.55	62.595
June	71.7	80.03	70.03	65.36	71.78
July	74.36	80.83	72.51	67.33	73.757
Aug.	71.45	80.03	71.76	66	72.31
Sept.	62.16	71	63.62	58.72	63.875
Oct.	47.87	57.96	51.9	46.51	51.06
Nov.	38.5	44.13	40.73	37.03	40.097
Dec.	27.54	35.2	31.66	27.08	30.37
Mean	49.511	57.332	50.812	46.186	50.96

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

	Hottest day. d. o	Coldest day. d. o	Greatest change within 24 hours. d. o	Range of each month
Jan.	19 43	31 2	4,27,28,31 23	41°
Feb.	24 51	1 1	3 32	50
Mar.	17 73	1 15	18 35	58
April	8 70	22 35	8 24	35
May	21 95	5 41	12 34	54
June	30 95.7	2 49	7 28	46.7
July	5 96.4	13 60	5 25.4	36.4
Aug.	5 94	27 52	6 26	42
Sept.	1 87	18 43	19 27	44
Oct.	10 77	29 28	16 35	49
Nov.	6 61	19 23	12 21	38
Dec.	8 43	26 0,5	26 33	42.5

Range of seasons and year.

Range of the year 95°.9.

Range of		
Winter	from 1° to 51°	50°
Spring	15 to 95	80
Summer	49 to 96.4	47.4
Autumn	23 to 87	64

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

Thermometer at 80° and upwards		Thermometer at 90° and upwards	
May	7 days	May	1 day
June	17	June	7
July	17	July	3
August	14	August	2
Septem.	6		13
	61	Hottest day July 5, 96.°4.	

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

Thermometer at 32° and under		Thermometer at 0° and under
January	26 days	
Feb.	22	0 day.
March	14	
October	4	Coldest day December 26, 0°.5.
Novem.	12	
Decem.	28	
	106	

	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of	27.928	50.313	72.615	51.677	50.633

1794. Second Series. 1795.

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.	Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.	24.26	32.774	29.06	24.87	27.741	Jan.	23.92	30.42	26.73	23.16	26.057
Feb.	24.5	32.75	28.11	23.71	27.267	Feb.	24.26	31.82	28.09	22.62	26.697
Mar.	37.258	46.225	40.387	35.161	39.757	Mar.	35.09	43.09	36.32	32.25	36.687
Apr.	47.56	56.56	48.48	43.26	48.965	April	45.83	53.4	46.24	41.63	46.775
May	59	66.31	57.82	54.73	59.465	May	57.06	64.7	56.32	52.87	57.737
June	67.5	74.86	66.03	61.1	67.372	June	68 2	75.83	65.28	60.33	67.41
July	74.29	80.83	71.79	67.48	73.597	July	72.03	79.06	70.13	65.74	71.74
Aug.	71.06	79.45	70.16	67.06	71.932	Aug.	73.41	81.64	74	70.16	74.802
Sept.	64.23	71.66	64.18	58.9	64.742	Sept.	63.93	72.66	65.26	59.76	65.402
Oct.	45.06	55.25	49.64	43.77	48.43	Oct.	50.16	60.96	55.33	49.74	54.047
Nov.	36.1	45.03	40.61	36.6	39.585	Nov.	36.23	47.36	42.33	37.03	40.737
Dec.	36.61	45.77	41.76	37.33	40.367	Dec.	31.3	38.5	35.27	30.9	33.992
Mean	48.952	57.289	50.668	46.164	50.768	Mean	48.451	56.62	50.108	45.515	50.173

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

	Hottest day. d.	°	Coldest day. d.	°	Gr'est change within 24 h'rs. d.	°	Range of each month		Hottest day. d.	°	Coldest day. d.	°	Gr'test change within 24 h'rs. d.	°	Range of each month
Jan.	10	53	25	5	13	32	48°	Jan.	30	45	16	7	15	24.5	38°
Feb.	11	41	5	5	7	26	36	Feb.	3	44	26	1.5	20	29	42.5
Mar.	23	69	4	4	23	37	65	Mar.	25	64	1	21	27	33	43
April	15	80	10	29	15	32	51	April	16	68	10	21	16	25	47
May	21	90	17	39	12	28	51	May	7	87	1	42	7	33	45
June	29	91	15	49	15&28	29	42	June	19	90	11	53	15	32	37
July	18	93	7	55	28	25	38	July	19	90	2	58	9	24	32
Aug.	4	91	13	57	4	26	34	Aug.	7	95	21	54	20	33	41
Sept.	1	88	30	39	30	36	49	Sept.	15	90	22	40	11	28	50
Oct.	12	69	16	32	18	31	37	Oct.	4	78	26	31	4	28	47
Nov.	4	69	26	16	27	35	53	Nov.	8	72	27	22	7	27	50
Dec.	17	62	29	22	16	26	40	Dec.	1	51	22	12	24	28	39

Range of seasons and year.

1794. Range of the year 89°. Range of Winter from 0°.5 to 83° — 82°.5; Spring " 4 to 90 — 86; Summer " 49 to 93 — 44; Autumn " 16 to 88 — 72.

1795. Range of the year 93°.5. Range of Winter from 1°.5 to 62° — 60°.5; Spring " 21 to 87 — 66; Summer " 53 to 95 — 42; Autumn " 22 to 90 — 68.

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1794. Thermometer at 80° and upwards		1794. Thermometer at 90° and upwards.		1795. Thermometer at 80° and upwards		1795. Thermometer at 90° and upwards	
April	1 day	May	1 day	May	3 days	June	1 day
May	3	June	1	June	10	July	2
June	8	July	3	July	14	August	9
July	18	August	1	August	13	Septem.	1
August	14		—	Septem.	10		—
Septem.	6		6		—		13
	—	Hottest day July 18, 93°.			55	Hottest day August 7, 95°.	
	50						

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1794. Thermometer at 32° and under		1794. Thermometer at 0° and under	1795. Thermometer at 32° and under		1795. Thermometer at 0° and under
January	24 days		January	30 days	
Feb.	27	0 day.	Feb.	27	0 day.
March	11		March	20	
April	2	Coldest day March 4, 4°.	April	3	Coldest day February 26, 1°.5.
October	1		October	1	
Novem.	14		Novem.	16	
Decem.	15		Decem.	21	
	—			—	
	94			118	

	Winter.	Spring.	Summer.	Autumn.	Seasons.	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of	28.439	49.395	70.967	50.919	49.93	31.04	47.066	71.317	53.395	50.704

1796. Second Series. 1797.

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.	Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.	25.6	34.03	29.19	24.21	28.257	Jan.	18.88	29.03	24.35	19.82	23.02
Feb.	24.58	34.55	29.41	23.88	28.105	Feb.	29.96	38.25	33.62	29.64	32.867
Mar.	33.13	40.32	34.93	30.12	34.625	Mar.	33.77	42.86	37.41	32.76	36.7
April	47.13	57.27	48.79	42.53	48.93	April	43.76	53.46	45.21	40.43	45.715
May	57.29	63.22	55.03	50.96	56.625	May	53.35	61.93	52.54	48.41	54.057
June	67.93	76.23	65.96	62.03	68.037	June	67.1	76.56	67.13	61.39	68.045
July	73.13	80.9	71.73	67.51	73.317	July	75.51	83.8	73.38	69.61	75.575
Aug.	71.4	81.46	71.64	65.16	72.415	Aug.	68.54	76.7	68.73	64.5	69.617
Sept.	60.56	70.93	62.93	57.2	62.905	Sept.	59.33	69.7	61.82	55.62	61.62
Oct.	47.06	56.61	50.66	45.8	50.032	Oct.	45.74	56.9	50.7	44.2	49.385
Nov.	33.26	42.56	38.13	34.46	37.102	Nov.	32.5	41.41	37.66	32.73	36.075
Dec.	19.58	29.19	25.08	21.33	23.795	Dec.	20.17	30.06	26.58	23	24.952
Mean	46.72	55.605	48.623	43.765	48.678	Mean	45.717	55.055	48.26	43.509	48.135

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

	Hottest day. d.	Hottest day. o	Coldest day. d.	Coldest day. o	Gr'est change within 24 hrs. d.	Gr'est change within 24 hrs. o	Range of each month		Hottest day. d.	Hottest day. o	Coldest day. d.	Coldest day. o	Gr'est change within 24 h'rs. d.	Gr'est change within 24 h'rs. o	Range of each month
Jan.	24	50	30	2.5	25	27	47°.5	Jan.	28	44	8	−10.5	26	37	54°.5
Feb.	28	48	5	5	6 & 11	28	43	Feb.	12	51	26	11	21	33	40
Mar.	13	60	8	10	8	23	50	Mar.	18	63	10	14	6	35	49
April	8	80	5	26	9	41	54	April	5	81	12	27	6	39	54
May	15	76	4	33	5	32	43	May	11	84	2	36	2	29	48
June	26	93	12	51	13	26	42	June	30	93	19	51	6 & 13	26	42
July	7	90	22	60	5,9,24	22	30	July	22	97	29	65	21	25	32
Aug.	29	93.5	30	54	1 & 18	25	39.5	Aug.	18	87	14	55	24	24	32
Sept.	15	84	26	45	27	23	39	Sept.	2	89	26	43	13	25	46
Oct.	23	73	28	32	29	28	41	Oct.	3	77	30	32	3	23	45
Nov.	19	55	27	11	16	31	44	Nov.	4	70	27	16	10	31	54
Dec.	5	42	24	−5.5	23	25	47.5	Dec.	14	60	21	−1.5	27	39	61.5

Range of seasons and year, 1796:
Range of the year 99°.
Range of { Winter from 2°.5 to 51° | 48°.5; Spring " 10 to 76 | 66; Summer " 51 to 93.5 | 42.5; Autumn " 11 to 84 | 73

Range of seasons and year, 1797:
Range of the year 107°.5.
Range of { Winter from −10°.5 to 51° | 61°.5; Spring " 14 to 84 | 70; Summer " 51 to 97 | 46; Autumn " 16 to 89 | 73

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1796.

Thermometer at 80° and upwards
- April 1 day
- June 12
- July 20
- August 18
- Septem. 5
- —
- 56

Thermometer at 90° and upwards
- June 3 days
- July 1
- August 5
- —
- 9

Hottest day August 29, 93°.5.

1797.

Thermometer at 80° and upwards
- April 1 day
- May 1
- June 12
- July 23
- August 8
- Septem. 3
- —
- 48

Thermometer at 90° and upwards
- June 3 days
- July 6
- —
- 9

Hottest day July 22, 97°.

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1796.

Thermometer at 32° and under
- January 26 days
- Feb. 25
- March 19
- April 2
- October 1
- Novem. 15
- Decem. 31
- —
- 119

Thermometer at 0° and under
- Decem. 2 days.

Coldest day Dec. 24, —5°.5.

1797.

Thermometer at 32° and under
- January 28 days
- Feb. 22
- March 18
- April 6
- October 1
- Novem. 19
- Decem. 28
- —
- 122

Thermometer at 0° and under
- January 4 days
- Decem. 2
- —
- 6

Coldest day January 8, — 10°.5.

	Winter.	Spring.	Summer.	Autumn.	Seasons	Winter.	Spring.	Summer.	Autumn.	Seasons,
Mean of	30.118	46.726	71.256	50.013	49.528	26.56	45.49	71.079	49.026	48.038

1798. **Second Series.** **1799.**

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.	Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.	23.87	32.23	28.38	24.09	27.142	Jan.	22.48	31.96	27.4	23.06	26.225
Feb.	22.67	31.03	27.1	22.5	25.825	Feb.	22.14	33.21	27.18	20.74	25.817
Mar.	33.64	43.22	37.38	32.46	36.675	Mar.	27.22	36.29	30.2	26.41	30.03
April	46.23	55.06	47.79	42.93	48.002	April	41.73	52.36	43.93	38.03	44.012
May	59.53	68.48	58.4	54.06	60.117	May	56.7	65.9	55.83	51.36	57.447
June	68.56	76.63	66.6	62.1	68.472	June	67.86	75.96	65.7	61.96	67.87
July	72.7	82.58	71.73	66.87	73.47	July	72.45	80.32	71	67.03	72.7
Aug.	74.7	83.83	75.13	69.45	75.777	Aug.	71.67	82.18	71.72	67	73.142
Sept.	62.6	72.06	65.17	59.86	64.922	Sept.	61.2	67.93	62	57.43	62.14
Oct.	49.77	59.32	53.96	49.29	53.085	Oct.	46.29	56.9	51.48	46.61	50.32
Nov.	32.63	42.1	37.46	33.41	36.4	Nov.	36.16	47.73	43	37.96	41.212
Dec.	19.7	28.93	25.64	20.8	23.767	Dec.	24.64	33.51	29.96	26.22	28.582
Mean	47 216	56.289	49.561	44.818	49.471	Mean	45.878	55.354	48.283	43.65	48.291

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month, and season and of the year.

1798.

	Hottest day. d.	o	Coldest day. d.	o	Gr'st change within 24 hs. d.	o	Range of each month.
Jan.	16	50	19	5	23	27	45°
Feb.	2	45	8	—2	5	27	47
Mar.	31	75	6	15	30	29	60
April	28	80	17	29	19	26	51
May	22	89	2	44	2	37	45
June	19	90	4	53	23	31	37
July	2	99	9	57	1	31	42
Aug.	9	99	1	60	17	26	39
Sept.	15	89	29	36	31	29	53
Oct.	2	73	30	28	30	23	45
Nov.	15	58	25	19	17	28	39
Dec.	1	46	12	2	5	33	44

Range of seasons and year.
Range of the year 101°.
Range of { Winter from —2° to 60° 62°; Spring " 15 to 89 74; Summer " 53 to 99 46; Autumn " 19 to 89 70 }

1799.

	Hottest day. d.	o	Coldest day. d.	o	Gr't change within 24 h. d.	o.	Range of each month.
Jan.	12	55	5	—8	5	30	63°
Feb.	9	50	25	5	23	32	45
Mar.	26	52	5	—4	5	32	56
April	18	74	10	28	8	28	46
May	15	88	12	37	16	33	51
June	23	93	1	44	17	31	49
July	5	94	3	58	5	27	36
Aug.	1	93	27	54	22	28	39
Sept.	2	82	30	44	3&12	19	38
Oct.	5	70	24	31	16	24	39
Nov.	18	65	21&28	21	19	29	44
Dec.	29	44	18	6	9	26	38

Range of seasons and year.
Range of the year 102°.
Range of { Winter from —8° to 55° 63°; Spring " —4 to 88 92; Summer " 44 to 94 50; Autumn " 21 to 82 61 }

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1798.

Thermometer at 80° and upwards

April	1 day
May	5
June	14
July	18
August	22
Septem.	5
	—
	65

Thermometer at 90° and upwards

June	1 day
July	7
August	7
	—
	15

Hottest days July 2, and August 9, each 99°.

1799.

Thermometer at 80° and upwards

May	5 days
June	14
July	17
August	19
Septem.	3
	—
	58

Thermometer at 90° and upwards

June	4 days
July	3
August	4
	—
	11

Hottest day July 5, 94°.

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1798.

Thermometer at 32° and under

January	28 days
Feb.	25
March	17
April	3
October	2
Novem.	19
Decem.	30
	—
	124

Thermometer at 0° and under

February 1 day

Coldest day February 8, — 2°.

1799.

Thermometer at 32° and under

January	28 days
Febru'y	27
March	22
April	8
October	3
Novem.	14
Decem.	27
	—
	129

Thermometer at 0° and under

January	1 day
March	1
	—
	2

Coldest day January 5, — 8°.

	Winter.	Spring.	Summer.	Autumn.	Seasons.	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of	25.975	48.264	72.573	51.469	49.569	25.269	43.829	71.237	51.224	47.889

Results of the 7 years' Therm. Observations, from 1793 to 1799 inclusive, or of the *second* series of observations.

	Mth.	1793	1794	1795	1796	1797	1798	1799	Mean.
Mean of each month in the years respectively, and of those years, and the mean of means.	Jan.	27.93	27.741	26.057	28.257	23.02	27.142	26.225	26.624
	Feb.	29.405	27.267	26.697	28.105	32.867	25.825	25.817	27.997
	Mar.	38.66	39.757	36.687	34.625	36.7	36.675	30.03	36.162
	April	49.685	48.965	46.775	48.93	45.715	48.002	44.012	47.44
	May	62.595	59.465	57.737	56.625	54.057	60.117	57.447	58.291
	June	71.78	67.372	67.41	68.037	68.045	68.472	67.87	68.426
	July	73.757	73.597	71.74	73.317	75.575	73.47	72.7	73.45
	Aug.	72.31	71.932	74.802	72.415	69.617	75.777	73.142	72.856
	Sept.	63.875	64.742	65.402	62.905	61.62	64.922	62.14	63.658
	Oct.	51.06	48.43	54.047	50.032	49.585	53.085	50.32	50.908
	Nov.	40.097	39.585	40.737	37.102	36.075	36.4	41.212	38.744
	Dec.	30.37	40.367	33.992	23.795	24.952	23.767	28.582	29.403
	Year	50.96	50.768	50.173	48.678	48.135	49.471	48.291	49.496
Mean of each time of obs. during the year and mean of means.	8 A.M.	49.511	48.952	48.451	46.72	45.717	47.216	45.878	47.492
	Noon	57.332	57.289	56.62	55.605	55.055	56.289	55.354	56.22
	Sunset	50.812	50.668	50.108	48.623	48.26	49.561	48.283	49.473
	10P.M.	46.186	46.164	45.515	43.765	43.509	44.818	43.65	44.801
	Mean								49.496
Mean of each season and mean of means.	Winter	27.928	28.439	31.04	30.118	26.56	25.973	25.269	27.903
	Spring	50.313	49.395	47.066	46.726	45.49	48.264	43.829	47.297
	Summer	72.615	70.967	71.317	71.256	71.079	72.573	71.237	71.577
	Autumn	51.677	50.919	53.395	50.013	49.026	51.469	51.224	51.103
	Mean	50.633	49.93	50.704	49.528	48.038	49.569	47.889	49.47

Mean of Spring and Autumn 49°.2. Mean of Winter and Summer 49°.74.

N. B. The mean of the year by civil reckoning does not agree exactly with that of the year as reckoned by the seasons, because they do not commence and terminate at the same time.

		1793	1794	1795	1796	1797	1798	1799	Mean
Gr'test change within 24 hours.		35°	37°	33°	41°	39°	37°	33°	36°.42
Days on which the therm. was at 80° & up. at 90° & up. at 32° & under, at 0° & und. & the means.	Days at 80°& up.	61 d.	50 d.	55 d.	56 d.	48 d.	65 d.	58 d.	56.14 days
	Days at 90°& up.	13	6	13	9	9	15	11	10.85 days
	Days at 32°& un.	106	94	118	119	122	124	129	116 days
	Days at 0°&und.	0	0	0	2	6	1	2	1.57 days
Hottest & cold. day, & means.	Hottest day.	96°.4	93°	95°	93°.5	97°	99°	94°	95°.41
	Coldest day.	0.5	4	1.5	—5.5	—10.5	—2	—8	-2.85
Range of seasons, months, and year, and the mean.	Annual range.	95.9	89	93.5	99	107.5	101	102	98°.27
	Greatest mo.rang.	58	65	50	54	61.5	60	63	58.78
	Least mo rang.	35	34	32	30	32	37	36	33.71
	Range	fr.1to51	0.5to53	1.5 to 62	2.5to51	—10 5to51	—2to60	—8to55	
	of Win.	50	52 5	60.5	48.5	61.5	62	63	56.85
		15to95	4to90	21 to 87	10to76	14 to 84	15 to 89	—4to88	
	Spr.	80	86	66	66	70	74	92	76.28
		49to96.4	49to93	53to95	51to93.5	51 to 97	53 to 99	44to94	
	Sum.	47.4	44	42	42 5	46	46	50	[illegible]5.41
		23to87	16to88	22to90	11 to 84	16 to 89	19 to 89	21 to 82	
	Aut.	64	72	68	73	73	70	61	68.71

Of the whole period.

Range of each season.

Winter	from —10.5 to 62	72°.5
Spring	from —4 to 95	99
Summer	from 44 to 99	55
Autumn	from 11 to 90	79

Greatest monthly range.
March 1794 | 65°

Least monthly range.
July 1795 and July and August 1797 | 32°

Greatest change within 24 hours.
From noon of April 8 to noon of 9th, 1796 | 41°

Hottest day.
August 9, 1798 | 99°

Coldest day.
January 8, 1797 | -10°.5

Range of the whole period.
From -10°.5 to 99° | 109°.5

1800. Third Series. 1801.

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.	Mth.	8 A. M.	Noon	Sunset.	10 P.M.	Mean.
Jan.	22.12	32.22	27.96	22.93	26.307	Jan.	22.06	31.29	27.83	24.83	26.502
Feb.	24.42	34.46	29.71	24.89	28.37	Feb.	25.35	35.64	29.64	24.85	28.87
Mar.	31.25	42.03	35.6	30.19	34.767	Mar.	37.38	43.48	38.64	35.96	38.865
April	48.56	58.66	50.03	45.26	50.627	April	45.8	53.56	45.96	41.79	46.777
May	54.89	63.63	55.68	52.17	56.592	May	59.25	68.61	59.17	55.64	60.667
June	69	80.03	68.06	62.43	69.88	June	67.03	76.2	65.24	60.8	67.317
July	74.74	83.95	72.74	68.67	75.025	July	73.41	82.03	70.39	67.06	73.222
Aug.	69.35	78.77	70.39	64.96	70.867	Aug.	70.44	79.96	71.24	65.33	71.742
Sept.	60.9	70.24	63.62	57.78	63.135	Sept.	64.5	73.9	66.22	60.28	66.225
Oct.	48.32	59.09	52.93	48.54	52.22	Oct.	48.9	61.9	55.11	47.74	53.412
Nov.	34.33	43.16	39	34.85	37.835	Nov.	35.96	46.66	41.63	37.06	40.327
Dec.	29.9	39	36.65	31.44	34.247	Dec.	27.03	36.19	32.93	28.9	31.262
Mean	47.315	57.103	50.197	45.342	49.989	Mean	48.093	57.45	50.333	45.853	50.432

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

1800.

Mth.	Hottest day. d.	Hottest day. °	Coldest day. d.	Coldest day. °	Gr'st change within 24 h'rs d.	Gr'st change within 24 h'rs °	Range of each month.
Jan.	16	50	29	—2	26	26	52°
Feb.	24	51	13	8	3	24	43
Mar.	27	62	6	9	27	28	53
April	19	82	1	35	18	34	47
May	28	77	7	42	7	27	35
June	12	92	5	53	5	29	39
July	31	100	2	55	18	29	45
Aug.	22	92	5	56	1	32	36
Sept.	13	91	24	48	22	28	43
Oct.	10	75	27	35	11	29	40
Nov.	8	59	25	19	19	24	40
Dec.	27	58	10	17	3	19	41

Range of seasons and year.
Range of the year 102°.
Range of { Winter from —2° to 51° = 53°; Spring " 9 to 82 = 73; Summer " 53 to 100 = 47; Autumn " 19 to 91 = 72 }

1801.

Mth.	Hottest day. d.	Hottest day. °	Coldest day. d.	Coldest day. °	Gr'st change within 24 h'rs d.	Gr'st change within 24 h'rs °	Range of each month.
Jan.	15	48	3	0	3	27	48°
Feb.	27	60	13	5	28	25	55
Mar.	1	55	5	23	4	27	32
April	30	72	11	33	28	25	39
May	30	90	4	45	28	28	45
June	28	92	6	46	5&10	31	46
July	2	96	18	57	1	29	39
Aug.	19	96	13	41	14	38	55
Sept.	8	94	27	43	11	28	51
Oct.	7	73	31	29	24	31	44
Nov.	28	64	21	19	5	29	45
Dec.	10	57	7	12	7	27	45

Range of seasons and year.
Range of the year 96°.
Range of { Winter from 0° to 60° = 60°; Spring " 23 to 90 = 67; Summer " 45 to 96 = 51; Autumn " 19 to 94 = 75 }

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1800.

Thermometer at 80° and upwards		Thermometer at 90° and upwards	
April	1 day	June	3 days
June	15	July	10
July	22	August	2
August	13	Septem.	1
Septem.	4		16
	55	Hottest day July 31, 100°.	

1801.

Thermometer at 80° and upwards		Thermometer at 90° and upwards	
May	3 days	May	1 day
June	12	June	3
July	17	July	6
August	15	August	2
Septem.	12	Septem.	2
	59		14
		Hottest day August 19, 96°.	

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1800.

Thermometer at 32° and under		Thermometer at 0° and under
January	28 days	January 2 days.
Feb'ry	23	
March	18	Coldest day January 29, —2°.
Novem.	16	
Decem.	21	
	106	

1801.

Thermometer at 32° and under		Thermometer at 0° and under
January	28 days	January 2 days.
Feb.	22	
March	9	Coldest day January 3, 0°.
October	3	
Novem.	19	
Decem.	23	
	104	

	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of (1800)	27.753	47.328	71.924	51.063	49.517
(1801)	29.873	48.769	70.76	53.321	50.68

1802. Third Series. 1803.

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.	Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.*	30.77	40.2	35.32	30.22	34.127	Jan.	24.38	33.58	29.31	25.29	28.14
Feb.	23.35	33.74	28.21	24.62	27.48	Feb.	28.6	38.1	33.59	30.4	32.672
Mar.	34.35	43.83	37.74	32.8	37.18	Mar.	34.06	43.74	37.5	32.58	36 97
April	45.06	55.06	46.5	41.36	46.995	Apr.	46.23	53.56	46.06	42.8	47.162
May	52.77	61.38	52.32	48.96	53.857	May	55.8	62.35	53.16	48.87	55.045
June	67.24	76.43	64.82	61.23	67.43	June	67.7	75.53	67	63.1	68.332
July	72 29	81.06	70.44	67.12	72.727	July	71.7	79.29	70.7	67.29	72.245
Aug.	72.09	79.25	71.32	67.73	72.597	Aug.	71.64	80.9	72.63	67.16	73.082
Sept.	63.63	73.37	66	59.93	65.732	Sept.	59.26	70.83	63.25	56.66	62.5
Oct.	52.58	61.96	55.48	51.8	55.455	Oct.	49.25	60.83	54.37	49.19	53.41
Nov.	37.93	49.75	44.67	38.43	42.695	Nov.	34.25	43.92	39.67	35.53	38.342
Dec.	29.01	38.16	35	30.87	33.26	Dec.	31.51	40.22	36.3	32.22	35.062
Mean	48.422	57.849	50.651	46.255	50.794	Mean	47.865	56.904	50.295	45.924	50.246

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

1802.

	Hottest day. d.	o	Coldest day. d.	o	Gr'est change within 24 h'rs. d.	o	Range of each month
Jan.	28	63	24	7	7	33	54°
Feb.	15	60	23	−3	7 & 9	31	63
Mar.	18	68	14	14	14	34	54
April	7	71	16	29	7	32	42
May	3	82	1	37	3	35	45
June	23	87	29	52	22	26	35
July	23	93	7	58	17	29	35
Aug.	1	94	19	61	31	24	33
Sept.	1	87	30	44	5	23	43
Oct.	10	81	30	33	12	23	48
Nov.	1	61	29	28	2	28	33
Dec.	28	62	17	−1.5	16	31	63.5

Range of seasons and year.

Range of the year 97°.

Range of				
Winter	from −3°	to 63°	66°
Spring	" 14	to 82	68
Summer	" 52	to 94	42
Autumn	" 28	to 87	59

1803.

	Hottest day. d.	o	Coldest day. d.	o	Gr'st change within 24 hrs. d.	o	Range of each month.
Jan.	12	56	4	4	3	34	52°
Feb.	13	56	4	8	4	36	48
Mar.	16	73	2	6	17	33	67
April	30	75	16	30	11	34	45
May	29	83	8	33	29	31	50
June	24	95	2	51	2	27	44
July	9	97	3	55	2	29	42
Aug.	28	94	23	58	25	27	36
Sept.	25	81	30	45	18	24	36
Oct.	2	77	18	34	1	29	43
Nov.	3	60	19	16	18	25	44
Dec.	1	59	22	13	1	30†	46

Range of seasons and year.

Range of the year 93°.

Range of				
Winter	from −1°.5	to 62°	63°.5
Spring	" 6	to 83	77
Summer	" 51	to 97	46
Autumn	" 16	to 81	65

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1802.

Thermometer at 80° and upwards

May	2 days
June	10
July	19
August	16
Septem.	9
October	3
	—
	59

Thermometer at 90° and upwards

July	5 days
August	3
	—
	8

Hottest day August 1, 94°.

1803.

Thermometer at 80° and upwards

May	2 days
June	10
July	13
August	17
Septem.	1
	—
	43

Thermometer at 90° and upwards

June	2 days
July	3
August	3
	—
	8

Hottest day July 9, 97°.

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1802.

Thermometer at 32° and under

January	20 days
Feb.	23
March	16
April	3
Novem.	9
Decem.	21
	—
	92

Thermometer at 0° and under

Febru'y	2 days
Decem.	1
	—
	3

Coldest day Feb. 23, —3°.

1803.

Thermometer at 32° and under

January	25 days
Feb.	19
March	15
April	3
Novem.	17
Decem.	22
	—
	101

Thermometer at 0° and under

0 day.

Coldest day January 4, 4°.

	Winter.	Spring.	Summer.	Autumn.	Seasons.	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of	30.956	46.01	70.918	54.627	50.6[illegible]	31.357	46.392	7[illegible].219	51.417	50.096

* The warmest January perhaps ever known.—*Dr. Holyoke.*

† Between sunset and 10 P. M.

1804. Third Series. 1805.

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.	Month	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.	20.62	29.3	26.67	21.54	24.532	Jan.	20.03	26.64	22.23	20.41	22.327
Feb.	24.79	33.75	29.27	24.17	27.995	Feb.	26.42	36.32	30.92	26.85	30.127
Mar.	31.61	41.25	35.03	29.64	34.382	Mar.	36.8	46.32	39.93	36.16	39.802
April	42.62	49.73	44.1	39.93	44.095	April	47.62	56.86	49.62	44.16	49.565
May	60.19	68.12	58.31	54.77	60.347	May	58.38	66.2	57.79	53.29	58.915
June	68.03	74 58	65.33	62.36	67.575	June	66.1	75.53	65.67	62.2	67.375
July	71.45	79.72	70.35	66	71.88	July	76.41	84.13	73.25	68.54	75.582
Aug.	68.4	77.56	68.8	63.77	69.632	Aug.	71.7	79.8	71.12	67.25	72.467
Sept.	61.53	71.08	63.89	58.26	63.69	Sept.	64.2	72.55	65.1	61.43	65.82
Oct.	44.7	55.96	50.13	44.8	48.897	Oct.	45.09	56.58	50.57	45.41	49.412
Nov.	35.96	46.62	41.86	36.73	40.292	Nov.	35.62	47.1	41.46	36.79	40.242
Dec.	23.93	30.89	27.32	24.34	26.62	Dec.	34.76	42.9	39 16	34.67	37.872
Mean	46.152	54.88	48.421	43.859	48.328	Mean	48.594	57.577	50.568	46.43	50.792

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

1804.

	Hottest day. d. o	Coldest day. d. o	Greatest change within 24 h'rs. d. o	Range of each month.
Jan.	17 43	21 1	18 (*t*) 26	42°
Feb.	22 49	24 9	16(*tn*)24	40
Mar.	27 57	4 8	5(*tn*)26	49
April	30 60	1 23	14(*tn*)22	37
May	8 87	16 43	18(*tn*)33	44
June	17 92	21 57	19(*n*) 28	35
July	30 95	18 55	7(*tn*)30	40
Aug.	19 90	28 54	19(*tn*)26	36
Sept.	2 93.5	3 37	10,22(*tn*)24	56.5
Oct.	5 74	31 31	14(*ne*)25	43
Nov.	3 65	17 21	28(*ne*)25	14
Dec.	1 47	14 –1	15 (*t*) 25	48

Range of seasons and year.
Range of the year 96°.
Range of { Winter from 1° to 59° | 58°; Spring " 8 to 87 | 70; Summer " 54 to 95 | 41; Autumn " 21 to 93.5 | 72.5

1805.

	Hottest day. d. o	Coldest day. d. o	Gr'test change within 24 h'rs. d. o	Range of each month.
Jan.	26 44	4 —3	13 (*e*) 29	47
Feb.	24 51	4 7	12(*nt*)19	44
Mar.	21 61	13 18	25(*tn*)30	43
April	18 79	6 35	14(*tn*)29	44
May	27 80	6 41	2(*tn*)28	39
June	25 95	9 49	14(*tn*)25	46
July	13 99.5	10 58	14(*ne*)34.5	41.5
Aug.	13 93	28 59	21(*tn*)26	34
Sept.	11 87.5	29 49	22(*ne*)26	38.5
Oct.	12 74	28 31	9(*tn*)26	43
Nov.	2 69	7 24	7(*ne*)26	45
Dec.	14 58	11 18	29 (*e*) 29	40

Range of seasons and year.
Range of the year 102°.5.
Range of { Winter from —3° to 51° | 54°; Spring " 18 to 80 | 62; Summer " 49 to 99.5 | 50.5; Autumn " 24 to 87.5 | 63.5

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1804.

Thermometer at 80° and upwards

May	3 days
June	6
July	16
August	10
Septem.	9
	—
	44

Thermometer at 90° and upwards

June	2 days
July	5
August	1
Septem.	2
	—
	10

Hottest day July 30, 95°.

1805.

Thermometer at 80° and upwards

May	1 day
June	11
July	21
August	16
Septem.	9
	—
	58

Thermometer at 90° and upwards

June	4 days
July	7
August	2
	—
	13

Hottest day July 13, 99°.5.

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1804.

Theamometer at 32° and under

January	30 days
Feb.	28
March	20
April	3
October	1
Novem.	12
Decem.	27
	—
	121

Thermometer at 0° and under

December 1 day

Coldest day December 14, —1°.

1805.

Thermometer at 32° and under

January	29 days
Feb.	23
March	10
October	2
Novem.	13
Decem.	17
	—
	94

Thermometer at 0° and under

January 1 day

Coldest day January 4, —3°.

	Winter.	Spring.	Summer.	Autumn.	Seasons.	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of	[illegible]9.196	46.274	69.695	50.959	49.031	26.358	49.427	71.808	51.824	49.854

1806. Third Series.

Mean of each time of observation, and of each month, at 4 observations per day.

Month.	8 A. M.	Noon.	Sunset.	10 P. M.	Mean.
Jan.	22.77	31.83	27.93	24.25	26.695
Feb.	28.08	37.5	32	28.1	31.42
March	28.58	37.5	31.41	27.96	31.362
April	39.6	47.33	41	36.7	41.157
May	56.35	62.77	54.22	50.13	55.867
June	65.63	75.6	64.82	60.8	66.712
July	69.74	77.41	68.55	63.93	69.907
Aug.	69.09	75.68	67.68	63.12	68.892
Sept.	59.16	68.9	61.83	57.63	61.88
Oct.	46.22	59.96	52.58	45.93	51.172
Nov.	36.46	45.8	41.76	37.06	40.27
Dec.	26.41	35·74	32.03	27.64	30.455
Mean	45.674	54.668	47.984	43.604	47.982

The hottest and coldest day; the greatest variation in any 24 hours; and the range of each month and season, and of the year.

	Hottest day. d.	°	Coldest day. d.	°	Greatest change within 24 hours. d.		°	Range of each month.
Jan.	30	50	15	0	20	(*e*)	25	50°
Feb.	27	55	6	8	6	(*ne*)	32	47
March	31	68	1	13	31	(*tn*)	31	55
April	4	68	11	23	4	(*tn*)	35	45
May	29	86	22	40	28	(*tn*)	30	46
June	23	93	2	49	5	(*nt*)	36	44
July	26	93	31	52	21	(*nt*)	25	41
Aug.	22	90	28	57	22	(*tn*)	30	33
Sept.	17	83	10	47	17	(*tn*)	25	36
Oct.	4	77	16	34	30	(*ne*)	29	43
Nov.	9	62	21	27	10	(*n*)	21	35
Dec.	26	50	31	5	11	(*se*)	25	45

Range of seasons and year.

Range of the year 93°.

Range of					
Winter	from	0°	to	53°	53°
Spring	"	13	to	86	73
Summer	"	49	to	93	44
Autumn	"	27	to	83	56

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

Thermometer at 80° and upwards		Thermometer at 90° and upwards	
May	2 days	June	2 days
June	8	July	2
July	15	August	1
August	8		5
September	3		
	36		

Hottest day July 23, 93°.

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

Thermometer at 32° and under		Thermometer at 0° and under	
January	29 days	January	1 day
February	21		
March	25		
April	7		
November	14		
December	28		
	124		

Coldest day January, 15, 0°.

	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of	31.995	42.795	68.503	51.107	48.6

Results of the 7 years' Therm. Observations, from 1800 to 1806 inclusive, or of the *third* series of observations.

	Mth.	1800	1801	1802.	1803.	1804.	1805.	1806	Mean
Mean of each month in the years respectively, and of those years, and the mean of means.	Jan.	26.307	26.592	34.127	28.14	24.532	22.327	26.695	26.947
	Feb.	28.37	28.87	27.48	32.672	27.995	30.127	31.42	29.562
	Mar.	34.767	38.865	37.18	36.97	34.382	39.802	31.362	36.189
	April	50.627	46.777	46.995	47.162	44.095	49.565	41.157	46.625
	May	56.592	60.667	53.857	55.045	60.347	58.915	55.867	57.327
	June	69.88	67.317	67.43	68.332	67.575	[illegible]7.375	66.712	67.803
	July	75.025	73.222	72.727	72.245	71.88	75.582	69.907	72.941
	Aug.	70.867	71.742	72.597	73.082	69.63[illegible]	72.467	68.892	71.325
	Sept.	63.135	66.225	65.732	62.5	63.69	55.82	[illegible]1.88	64.14
	Oct.	52.22	53.412	55.455	53.41	48.897	49.412	51.172	51.996
	Nov.	37.835	40.327	42.695	38.342	40.292	40.242	[illegible]0.27	40
	Dec.	34.247	31.262	33.26	35.062	26.62	37.872	30.455	32.682
	Year	49.989	50.432	50.794	50.246	48.328	50.792	47.982	49.794
Mean of each time of obs. during the year, and mean of means.	8 A.M	47.315	48.092	48.422	47.865	46.15	48.594	45.674	47.444
	Noon	57.103	57.451	57.849	56.904	54.88	57.577	54.668	56.633
	Sunset	50.[illegible]97	50.333	50.651	50.295	48.421	50.568	47.984	49.778
	10P.M.	45.342	45.853	46.255	45.924	43.859	46.43	43.604	45.323
	Mean								49.794
Mean of each season and mean of means.	Winter	27.753	29.873	30.956	31.357	29.196	26.358	31.995	29.641
	Spring	47.328	48.769	46.01	46.392	46.274	49.427	42.795	46.713
	Summer	71.924	70.76	70.918	71.219	69.695	71.808	68.503	70.689
	Autumn	51.063	53.321	54.627	51.417	50.959	51.824	51.107	52.045
	Mean	49.517	50.68	50.627	50.096	49.031	49.854	48.6	49.772

Mean of Spring and Autumn 49°.379. Mean of Winter and Summer 50°.165.

N. B. The same remark may be made in this place, as in the corresponding one of the Results of the Second Series.

		1800	1801	1802	1803	1804	1805	1806	Mean
Gr'test change within 24 hours.		34°	38°	35°	36°	33°	34.5°	36°	35°.21
Days on which the therm. was at 80° & up, at 90° & up, at 32° & under, at 0° & und. & the means.	Days at 80° & up.	55 d.	59 d.	59 d.	43 d.	44 d.	58 d.	36 d.	50.57 days
	Days at 90° & up.	16	14	8	8	10	13	5	10.57 days
	Days at 32° & un.	106	104	92	101	121	94	124	106 days
	Days at 0° & und.	2	2	3	0	1	1	1	1.42 days
Hottest & cold. day, & means.	Hottest day.	100°	96°	94°	97°	95°	99.5°	93°	96°.35
	Coldest day.	—2	0	—3	4	—1	—3	0	-0.71
Range of seasons, months, and year, and the mean.	Annual range.	102	96	97	93	96	102.5	93	97°07
	Greatest mo. rang.	53	55	63.5	67	56.5	47	55	56·71
	Least mo rang.	35	32	33	36	35	34	33	34
	Range of Win.	fr.-2to51	0to60	-3to63	-1 5to62	1 to 50	—3 to 51	0 to 58	
		53	60	66	63 5	58	54	58	58.92
	Spr.	9to82	23to90	14to82	6 to 83	8 to 87	18 to 80	13 to 86	
		73	67	68	77	79	62	73	71.28
	Sum.	53to100	45to96	52to94	51 to 97	54 to 95	49to99.5	49to93	
		47	51	42	46	41	50.5	44	45.92
	Aut.	19to91	19to94	28to87	16 to 81	21to93.5	24to87.5	27to83	
		72	75	59	65	72.5	63.5	56	66.14

Of the whole period.

Range of each season.

Winter from —3° to 63°	66°.
Spring from 6 to 90	84
Summer from 45 to 100	55
Autumn from 16 to 94	78

Greatest monthly range.

March 1803	67°

Least monthly range.

March 1801	32°

Greatest change within 24 hours.

From 10 P. M. Aug. 13, to noon Aug. 14 } 1801	38°

Hottest day.

July 31, 1800	100°

Coldest day.

February 23, 1802	—3°

Range of the whole period.

From —3° to 100°	10[illegible]

1807. Fourth Series. 1808.

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.	Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.	18.48	29.2	24.36	20.91	23.237	Jan.	20.87	31.45	27.7	23.58	25.9
Feb.	20.82	31.75	26.78	21.75	25.275	Feb.	27.75	36.72	31.82	27.75	31.01
Mar.	29.45	39	35.38	28.32	32.537	Mar.	35.8	45.61	39.83	34.61	38.962
April	44	52.06	44.63	41.73	45.605	April	45.93	53.63	46.4	42.56	47.13
May	54.26	62.87	53.26	49.83	55.055	May	55.19	62.41	52.62	50.56	55.195
June	64.63	73.7	64.79	59.83	65.737	June	66.73	75.16	65.55	61.43	67.217
July	72.29	80.32	70.96	66.61	72.545	July	71.43	80.09	70.35	66.58	72.112
Aug.	69.93	77.9	69.39	65.25	70.617	Aug.	66.96	77.22	68.58	62	68.69
Sept.	57.53	68.73	60.64	55.73	60.657	Sept.	61.43	72.5	64.42	58.7	64.262
Oct.	47.7	60	52.61	46.7	51.752	Oct.	46.67	55.7	49.75	46.43	49.637
Nov.	34.85	43.93	39.48	35.62	38.47	Nov.	37	46.86	43.06	39.06	41.495
Dec.	32.5	41.8	36.71	33.41	36.105	Dec.	28.8	36.36	33.12	30.6	32.22
Mean	45.536	55.105	48.082	43.807	48.132	Mean	47.046	56.142	49.433	45.321	49.485

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

1807.

Mth.	Hottest day. d.	o	Coldest day. d.	o	Gr'test change within 24 h'rs. d.	o	Range of each month
Jan.	5	48	26	−6.5	24 (*e*)	38	54°.5
Feb.	15	45	8	−3	16(*ne*)	42	48
Mar.	22	49	2	18	17(*tn*)	28	31
April	20	73	1	30	7(*tn*)	26	43
May	29	79	10	38	12(*tn*)	27	41
June	10	92	1	47	15(*tn*)	29	45
July	13	92	2	57	3(*tn*)	24	35
Aug.	10	89	23	57	1,27(*tn*)	22	32
Sept.	7	78	14	40	14 (*s*)	29	38
Oct.	14	79	28	30	19(*ne*)	30	49
Nov.	27	58	17	20	28 (*t*)	23	38
Dec.	14	54	20	15	24(*ne*)	26	39

Range of seasons and year.
Range of the year 98°.5.
Range of { Winter from −6°.5 to 50° 56°.5; Spring " 18 to 79 61; Summer " 47 to 92 45; Autumn " 20 to 79 59 }

1808.

Mth.	Hottest day. d.	o	Coldest day. d.	o	Gr'st change within 24h'rs. d.	o	Range of each month.
Jan.	27	46	16	2	28 (*t*)	30	44°
Feb.	29	54	19	6	26(*ne*)	24	48
Mar.	5	68	7	16	6 (*n*)	38	52
April	29	74	10	29	14(*tn*)	27	45
May	2,31	80	8	43	2(*tn*)	30	37
June	27	94	19	48	5(*tn*)	30	46
July	17	98	9	59	1(*tn*)	31	39
Aug.	4	96	16	53	25(*tn*)	31	43
Sept.	19	90	21	40	1(*tn*)	26	50
Oct.	1	73	28	25	18 (*t*)	27	48
Nov.	10	65	27	23	8(*tn*)	24	42
Dec.	23	56	8	10	25 (*e*)	31	46

Range of season and years.
Range of the year 96°.
Range of { Winter from 2° to 54° 52°; Spring " 16 to 80 64; Summer " 48 to 98 50; Autumn " 23 to 90 67 }

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1807.

Thermometer at 80° and upwards		Thermometer at 90° and upwards	
June	9 days	June	2 days
July	15	July	2
August	13		—
	—		4
	37	Hottest day June 10, 92°.	

1808.

Thermometer at 80° and upwards		Thermometer at 90° and upwards	
May	2 days	June	4 days
June	12	July	3
July	16	August	1
August	9	Septem.	1
Septem.	8		—
	—		9
	47	Hottest day July 17, 98°.	

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1807.

Thermometer at 32° and under		Thermometer at 0° and under	
January	30 days	January	4 days
Feb.	27	Feb.	1
March	28		—
April	4		5
October	3		
Novem.	15		
Decem.	20	Coldest day January 26, —6°.5.	
	—		
	127		

1808.

Thermometer at 32° and under		Thermometer at 0° and under
January	27 days	0 day
Feb.	21	
March	14	Coldest day January 16, 2°.
April	2	
October	4	
Novem.	11	
Decem.	22	
	—	
	101	

	Winter.	Spring.	Summer.	Autumn.	Seasons.	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of	26.322	44.399	69.633	50.293	47.661	31.005	47.095	69.339	51.798	49.809

1809. Fourth Series. 1810.

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.	Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.	18.48	28.77	24.19	20.64	23.02	Jan.	21.38	31.93	27.13	22.95	25.847
Feb.	19.17	30.42	25.17	20.96	23.93	Feb.	24.28	37.6	31.71	26.28	29.967
Mar.	29.25	38.61	32.44	29.29	32.397	Mar.	30.96	41	34.1	29.64	33.925
April	44.37	55.7	45.85	42.03	46.987	April	45.53	56.6	46.86	42.5	47.872
May	55.48	64.74	54.03	51.06	56.327	May	57.62	69.41	56.68	51.37	58.77
June	66.41	74.46	63.3	60.6	66.192	June	67	75.73	64.44	61.76	67.232
July	67.48	75.96	66.43	62.77	68.16	July	69.57	79.46	68.51	63.83	70.342
Aug.	67.5	77.7	67.34	63.12	68.915	Aug.	68.58	77.09	68.6	64.76	69.757
Sept.	57.06	70.03	61.46	55.13	60.92	Sept.	61.83	71.06	63.63	59.82	64.085
Oct.	52.61	66.21	59.68	53.48	57.995	Oct.	46.23	58.96	52.1	46.7	50.997
Nov.	31.33	39.66	36.08	33.01	35.02	Nov.	35.43	44.63	40.63	36.9	39.397
Dec.	32.25	39.16	35.96	33.35	35.18	Dec.	25	35.22	31.31	27.79	29.83
Mean	45.115	55.118	47.66	43.786	47.92	Mean	46.117	56.557	48.808	44.525	49.001

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

1809	Hottest day. d.	Hottest day. o	Coldest day. d.	Coldest day. o	Gr'test change within 24 hrs. d.	o	Range of each month.
Jan.	20	48	13	4	21(*ne*)	30	44°
Feb.	26	43	9	1	13(*tn*)	37	42
Mar.	20	51	14	14	13(*ne*)	25	37
April	18	79	9	32	1(*tn*)	34	47
May	22	82	11	42	31(*tn*)	24	40
June	12	90	3	53	12(*tn*)	31	37
July	10	94	18	54	1(*tn*)	26	40
Aug.	5	94	25	55	5(*tn*)	28	39
Sept.	11	85	16	45	30(*tn*)	32	40
Oct.	10	87.5	26	35	1(*tn*)	30	52.5
Nov.	3	68	23	15	4(*ts*)	29.5	53
Dec.	7	63	24	8	8(*ne*)	31	55

Range of seasons and year (1809): Range of the year 93°. Range of { Winter from 1° to 56° \| 55°; Spring " 14 to 82 \| 68; Summer " 53 to 94 \| 41; Autumn " 15 to 87.5 \| 72.5 }

1810	Hottest day. d.	Hottest day. o	Coldest day. d.	Coldest day. o	Gr'st change within 24h'rs. d.	o	Range of each month.
Jan.	6	54	20	−5	19(*ne*)	41	59°
Feb.	26	66	10	−3	10(*ne*)	50	69
Mar.	28	51	16	17	3(*ne*)	25	34
April	21	80	3	25	19(*tn*)	31	55
May	29	97	6	40	30(*ne*)	37	57
June	25	91	8	45	1(*tn*)	27	46
July	8	91	17	54	8(*nt*)	31	37
Aug.	12	89	20	58	4(*tn*)	24	31
Sept.	6	84	16	45	28(*tn*)	23	39
Oct.	1	83	31	25	23(*ne*)	33	58
Nov.	15	62	25	20	21(*ne*)	30	42
Dec.	29	55	18	8	26(*ne*)	35	47

Range of seasons and year (1810): Range of the year 102°. Range of { Winter from −5° to 66° \| 71°; Spring " 17 to 97 \| 80; Summer " 45 to 91 \| 46; Autumn " 20 to 84 \| 64 }

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1809. Thermometer at 80° and upwards: May 1 day; June 8; July 7; August 11; Septem. 4; October 6; — 37

Thermometer at 90° and upwards: June 1 day; July 2; August 1; — 4

Hottest day July 10, 94°.

1810. Thermometer at 80° and upwards: April 1 day; May 6; June 12; July 12; August 12; Septem. 9; October 3; — 55

Thermometer at 90° and upwards: May 2 days; June 1; July 1; — 4

Hottest day May 29, 97°.

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1809. Thermometer at 32° and under: January 30 days; Feb'ry 26; March 20; April 1; Novem. 22; Decem. 20; — 119

Thermometer at 0° and under: 0 day

Coldest day February 9, 1°.

1810. Therm. at 32° and under: January 26 days; Feb. 24; March 23; April 4; October 5; Novem. 16; Decem. 29; — 127

Thermometer at 0° and under: January 6 days; Feb'ry 2; — 8

Coldest day January 20, −5°.

Mean of	Winter.	Spring.	Summer.	Autumn.	Seasons.
1809	26.39	45.237	67.755	51.311	47.673
1810	30.331	46.855	69.11	51.493	49.447

1811. Fourth Series. 1812.

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.	Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.	21.35	30.8	27.96	25	26.277	Jan.	19.16	26.93	22.79	19.98	22.215
Feb.	24.78	33.5	28.1	26.17	28.137	Feb.	21.24	30.41	26.06	23.13	25.21
Mar.	35.93	46.93	39.09	35.16	39.277	Mar.	26.16	35.35	29.9	26.29	29.425
April	44.41	54.5	44.92	41.28	46.277	April	42.51	50.46	43.03	39.76	43.94
May	56.62	67.93	56.79	51.96	58.325	May	48.8	55.87	48.1	45.7	49.617
June	68.1	76.8	65.36	62.1	68.09	June	61.26	69.93	60.96	58.06	62.552
July	71.68	80.48	70.71	68.33	72.8	July	67.1	75.8	65.28	62.37	67.637
Aug.	70	78.53	70.16	65.1	70.947	Aug.	65.06	74.09	66.35	62.22	66.93
Sept.	61.13	73.3	64.44	58.56	64.357	Sept.	55.1	65.66	58.75	54.03	58.385
Oct.	50.96	62.16	55.8	51.76	55.17	Oct.	46.64	57.67	51.41	46.64	50.59
Nov.	37.13	47.3	42.72	38.63	41.445	Nov.	33.96	43.85	38.85	35	37.915
Dec.	26.22	34.74	31.16	27.16	29.82	Dec.	24.83	33.38	30.51	27.06	28.945
Mean	47.359	57.247	49.767	45.934	50.076	Mean	42.651	51.616	45.165	41.686	45.28

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

1811.

	Hottest day. d.	°	Coldest day. d.	°	Gr'test change within 24 hr's. d.	°	Range of each month.
Jan.	7	55	24	1	23(*ne*)	36	54°
Feb.	28	50	22	3	14(*ne*)	25	47
Mar.	21	68	8	16	21(*nt*)	33	52
April	17	74	2	27	14(*tn*)	32	47
May	26	78	2	41	4,31(*tn*)	25	37
June	22	96	30	52	15,20(*tn*)	29	44
July	5	100	11	51	2(*tn*)	30	49
Aug.	20	97	8	56	3(*tn*)	24	41
Sept.	4	90	21	43	20(*ne*)	25	47
Oct.	12	84	27	31	21(*ne*)	39	53
Nov.	17	60	26	14	18(*ne*)	31	46
Dec.	4	54	24	3	20 (*e*)	36	51

Range of seasons and year: Range of the year 99°. Range of Winter from 1° to 55° — 54°; Spring " 16 to 78 — 62; Summer " 51 to 100 — 49; Autumn " 14 to 90 — 76.

1812.

	Hottest day. d.	°	Coldest day. d.	°	Gr'test change within 24 h'rs. d.	°	Range of each month.
Jan.	26	43	18	−6	23(*tn*)	32.5	49°
Feb.	8	45	27	2	27(*ne*)	35	43
Mar.	27	53	2	6	5(*tn*)	30	47
April	18	77	12	30	18(*tn*)	32	47
May	31	80	4	33	1(*nt*)	22	47
June	20	87	13	48	5,19(*tn*)	27	39
July	4	89	16	53	17(*tn*)	27	36
Aug.	10	87	27	52	27(*ne*)	26	35
Sept.	13	84	28	38	14(*ne*)	25	46
Oct.	2	76	13	32	15(*tn*)	26	44
Nov.	5	70	25	22	25(*ne*)	28	52
Dec.	5	54	26	8	25(*ne*)	26	46

Range of seasons and year: Range of the year 95°. Range of Winter from —6° to 54° — 60°; Spring " 6 to 80 — 74; Summer " 48 to 89 — 41; Autumn " 22 to 84 — 62.

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1811. Thermometer at 80° and upwards: June 12 days; July 13; August 11; Septem. 7; October 3; — 46.

Thermometer at 90° and upwards: June 2 days; July 7; August 2; Septem. 1; — 12. Hottest day July 5, 100°.

1812. Thermometer at 80° and upwards: May 1 day; June 6; July 8; August 12; Septem. 2; — 29.

Thermometer at 90° and upwards: 0 day. Hottest day July 4, 89°.

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1811. Thermometer at 32° and under: January 25 days; Feb. 24; March 15; April 3; October 1; Novem. 11; Decem. 24; — 103.

Thermometer at 0° and under: 0 day. Coldest day January 24, 1°.

1812. Thermometer at 32° and under: January 29 days; Febru'y 28; March 24; April 4; October 2; Novem. 20; Decem. 26; — 133.

Thermometer at 0° and under: January 4 days. Coldest day January 18, — 6°.

	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of 1811	28.081	47.959	70.612	53.657	50.077
Mean of 1812	25.748	40.994	65.706	48.963	45.352

1813. Fourth Series.

Mean of each time of observation, and of each month, at 4 observations per day.

Month.	8 A. M.	Noon.	Sunset.	10 P. M.	Mean.
Jan.	18.83	28.03	24.61	21.16	23.157
Feb'ry	23.14	32.78	27.53	24.82	27.067
March	27	34.61	30.54	26.77	29.73
April	44.83	53.3	46.37	41.36	46.465
May	52.06	61.45	51.96	48.87	53.585
June	65	72.96	62.7	59.3	64.99
July	68.45	78.22	68	64.58	69.812
Aug.	69.32	80.9	70.53	65.7	71.612
Sept.	62.9	72.73	64.89	60.83	65.337
Oct.	47.64	55.51	50.44	45.83	49.855
Nov.	37.75	47.63	44.03	37.82	41.807
Dec.	24.74	34.83	30.83	25.64	29.01
Mean	45.138	54.412	47.702	43.556	47.702

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

	Hottest day. d.	°	Coldest day. d.	°	Greatest change within 24 hours. d.	°	Range of each month. °
Jan.	2	45	30	-7	30	39	52
Feb'ry	8,25	44	2	3	26	34	41
March	23	55	6	1	6	34	54
April	21	73	1&2	30	11	35	43
May	24	88	2&3	38	24,30	29	50
June	28	93	10	51	28	28	42
July	9	93	12	58	10	29	35
Aug.	7&9	92	25	58	7	28	34
Sept.	13	93	25	49	20	26	44
Oct.	27	67	21	26	20,31	24	41
Nov.	10	62	29	28	9	25	34
Dec.	1	50	25,26	5	25	36	45

Range of seasons and year.

Range of the year 100°.

Range of	from	to	
Winter	—7°	54°	61°.
Spring	1	88	87
Summer	51	93	42
Autumn	26	93	67

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

Thermometer at 80° and upwards		Thermometer at 90° and upwards	
May	2 days	June	1 day
June	8	July	3
July	11	August	3
August	18	September	2
September	7		9
	46		

Hottest days June 28, July 9, and Sept. 13, each 93°.

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

Thermometer at 32° and under		Thermometer at 0° and under	
January	30 days	January	3 days.
February	26		
March	23		
April	3		
October	4		
November	9		
December	25		
	120		

Coldest day January 30, —7°.

	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of	26.389	43.26	68.804	52.333	47.696

Results of the 7 years' Therm. Observations, from 1807 to 1813 inclusive, or of the *fourth* series of observations.

	Mth.	1807	1808	1809	1810	1811	1812	1813	Mean.
Mean of each month in the years respectively, and of those years, and the mean of means.	Jan.	23.237	25.9	23.02	25.847	26.277	22.215	23.157	24.236
	Feb.	25.275	31.01	23.93	29.967	28.137	25.21	27.067	27.228
	Mar.	32.537	38.962	32.397	33.925	39.277	29.425	29.73	33.75
	April	45.605	47.13	46.987	47.872	46.277	43.94	46.465	46.325
	May	55.055	55.195	56.327	58.77	58.325	49.617	53.585	55.267
	June	65.737	67.217	66.192	67.232	68.09	62.552	64.99	66.001
	July	72.545	72.[illegible]12	68.16	70.342	72.8	67.637	69.812	70.486
	Aug.	70.617	68.69	68.915	69.757	70.947	66.93	71.612	69.638
	Sept.	60.607	64.262	60.92	64.085	64.357	58.385	65.337	62.571
	Oct.	51.752	49.637	57.995	50.997	55.17	50.59	49.855	52.285
	Nov.	38.47	41.495	35.02	39.397	41.445	37.915	41.807	39.364
	Dec.	36.105	32.22	35.18	29.83	29.82	28.945	29.01	31.587
	Year	48.132	49.485	47.92	49.001	50.076	45.28	47.702	48.228
Mean of each time of obs. during the year, and mean of means.	8 A.M.	45.536	47.046	45.115	46.117	47.359	42.651	45.138	45.566
	Noon	55.105	56.142	55.118	56.557	57.247	51.616	54.412	55.171
	Sunset	48.082	49.433	47.66	48.808	49.767	45.165	47.702	48.088
	10P.M.	43.807	45.321	43.786	44.525	45.934	41.686	43.556	44.087
	Mean								48.228
Mean of each season and mean of means.	Winter	26.322	31.005	26.59	30.331	28.081	25.748	26.389	27.752
	Spring	44.399	47.095	45.237	46.855	47.959	40.994	43.26	45.114
	Summer	69.635	69.339	67.755	69.11	70.612	65.706	68.804	68.707
	Autumn	50·293	51.798	51.311	51.493	53.657	48.963	52.333	51.406
	Mean	47.661	49.809	47.673	49.447	50.077	45.352	47.696	48.245

Mean of Spring and Autumn 48°.26. Mean of Winter and Summer 48°.229.

N. B. The same remark may be made in this place, as in the corresponding one of the Results of the Second Series.

		1807	1808	1809	1810	1811	1812	1813	Mean
Gr'test change within 24 hours.		° 42	° 38	° 37	° 50	° 39	° 35	° 39	° 40
Days on which the therm. was at 80° & up. at 90° & up. at 32° & under, at 0° & und. & the means.	Days at 80°& up.	d. 37	d. 47	d. 37	d. 55	d. 46	d. 29	d. 46	days 42.42
	Days at 90°& up.	4	9	4	4	12	0	9	days 6
	Days at 32°& un.	127	101	119	127	103	133	120	days 118.5
	Days at 0°&und.	5	0	0	8	0	4	3	days 2.85
Hottest & cold. day, & means.	Hottest day.	° 92	° 98	° 94	° 97	° 100	° 89	° 93	94°.71
	Coldest day.	−6.5	2	1	−5	1	−6	−7	−2.92
Range of seasons, months, and year, and the mean.	Annual range.	98.5	96	93	102	99	95	100	97°.64
	Greatest mo.rang.	54.5	52	55	69	54	52	54	55.78
	Least mo.rang.	31	37	37	31	37	35	34	34.57
	Range	−6.5to50	2to54	1to56	−5to66	1to55	−6 to 54	−7to 54	
	of Win.	56.5	52	55	71	54	60	61	58.5
		18to79	16to80	14to82	17 to 97	16 to 78	6 to 80	1 to 88	
	Spr.	61	64	68	80	62	74	87	70.85
		47to92	48to98	53to94	45 to 91	51 to 100	48to89	51to93	
	Sum.	45	50	41	46	49	41	42	44.85
		20to79	23to90	15to87.5	20 to 84	14to90	22to84	26to93	
	Aut.	59	67	72.5	64	76	62	67	66.78

Of the whole period.

Range of each season.

Winter	from −7° to 66°	73°.
Spring	from 1 to 97	96
Summer	from 45 to 100	55
Autumn	from 14 to 93	79

Greatest monthly range.
February 1810 | 69°

Least monthly range.
March 1807 & August 1810 | 31°

Greatest change within 24 hours.
From noon Feb. 9 to 8 A. M. Feb. 10 } 1810 | 50°

Hottest day.
July 5, 1811 | 100°

Coldest day.
January 30, 1813 | −7°

Range of the whole period.
From −7° to 100° | 107°

1814. Fifth Series. 1815.

Mean of each time of observation, and of each month, at 4 observations per day.

1814.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.	18.8	30.09	25.83	21.12	23.96
Feb.	24.5	35.14	31.28	27.64	29.64
Mar.	30.64	41.32	34.54	30.83	34.332
April	45.86	56.7	48.17	44.2	48.732
May	57.67	66.29	56.41	53.96	58.582
June	63.93	71.23	61	58.16	63.58
July	70.77	80.64	70.33	65.32	71.765
Aug.	67.64	75.93	67.56	62.9	68.507
Sept.	58.8	68.86	61.8	57.63	61.772
Oct.	46.09	59.93	52.17	46.25	51.11
Nov.	35.76	46.3	42.55	38.63	40.81
Dec.	22.	32.22	27.8	24.29	26.577
Mean	45.205	55.387	48.286	44.244	48.279

1815.

Month.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.	19.32	29.32	25	20.41	23.512
Feb.	18.07	30.82	24.92	19.71	23.38
Mar.	33	41.9	36.55	32.93	36.095
April	41.73	49.72	42.06	38.46	42.992
May	52.1	61.06	52.55	48.37	53.52
June	65.73	76.66	64.6	60.06	66.762
July	73.45	84.32	72.96	69.06	74.947
Aug.	65.31	74.19	64.96	61.67	66.532
Sept.	59.27	69.96	61.6	56.9	61.932
Oct.	45.58	57.68	50.03	45.51	49.7
Nov.	37.6	48.4	44.24	39.13	42.342
Dec.	24.45	35.41	31.29	27.16	29.577
Mean	44.634	54.953	47.563	43.28	47.607

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

1814.

	Hottest day. d.	Hottest day. °	Coldest day. d.	Coldest day. °	Gr'test change within 24 h'rs. d.	Gr'test change within 24 h'rs. °	Range of each month.
Jan.	25	44	31	−3	31	43	47°
Feb.	18	50	4	−4	4	39	54
Mar.	27	62	5	8	28,30	26	54
April	26	90	24	32	26	47	58
May	26	92	2	40	27	23	52
June	29	87	7	47	29	31	40
July	15	93	12	52	15	26	41
Aug.	17	91	22	52	30	26	39
Sept.	3	90	26	45	5	34	45
Oct.	15	77	25	29	16	35	48
Nov.	14	62	29	15	15	28	47
Dec.	31	43	26	1	20	28	42

Range of seasons and year. Range of the year 97°.

Range of			
Winter	from −4° to 50°	54°
Spring	" 8 to 92	84
Summer	" 47 to 93	46
Autumn	" 15 to 90	75

1815.

	Hottest day. d.	Hottest day. °	Coldest day. d.	Coldest day. °	Gr'est change within 24 h'rs. d.	Gr'est change within 24 h'rs. °	Range of each month.
Jan.	1	51	31	−9	29	27	60°
Feb.	28	43	1	3	1	30	40
Mar.	15	60	21	10	16	30	50
April	27	83	1	28	28	34	55
May	22	81	3	37	19	28	44
June	20	94	1	51	11,20	29	43
July	25	99	26	61	26	36	38
Aug.	1	98	11	56	1	32	42
Sept.	11	90	28	45	12	26	45
Oct.	1	79	31	25	23	29	54
Nov.	2	64	8	22	11	30	42
Dec.	24	52	11	8	5	28	44

Range of seasons and year. Range of the year 108°.

Range of		
Winter	from −9° to 51°	60°
Spring	" 10 to 83	73
Summer	" 51 to 99	48
Autumn	" 22 to 90	68

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1814.

Thermometer at 80° and upwards

April	2 days
May	2
June	2
July	19
August	8
Septem.	6
	39

Ther. at 90° and upwards

April	1 day
May	1
July	4
August	2
Septem.	2
	10

Hottest day July 15, 93°.

1815.

Thermometer at 80° and upwards

April	1 day
May	1
June	14
July	22
August	6
Septem.	4
	48

Thermometer at 90° and upwards

June	3 days
July	10
August	1
Septem.	1
	15

Hottest day July 25, 99°.

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1814.

Theamometer at 32° and under

January	30 days
Feb.	23
March	19
April	1
October	3
Novem.	12
Decem.	30
	118

Thermometer at 0° and under

January	3 days
February	1
	4

Coldest day February 4, —4°.

1815.

Thermometer at 32° and under

January	27 days
Feb.	27
March	20
April	5
October	4
Novem.	12
Decem.	26
	121

Thermometer at 0° and under

January 4 days

Coldest day January 31, —9°.

	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of 1814	27.53	47.215	67.949	51.23	48.482
Mean of 1815	24.489	44.202	69.412	51.324	47.356

1816. Fifth Series. 1817.

Mean of each time of observation, and of each month, at 4 observations per day.

Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.	Mth.	8 A. M.	Noon.	Sunset.	10 P.M.	Mean.
Jan.	19.45	31.61	27.06	22.93	25.262	Jan.	19.83	29.54	25.24	21.48	24.02
Feb.	23.85	33.48	29.31	25.31	27.987	Feb.	14.75	27.08	21.37	16.78	19.99
Mar.	27.29	37.22	31.2	26.93	30.66	Mar.	28.67	39.09	32.66	28.58	32.25
April	42.37	52.83	45.13	40.93	45.315	Apr.	41.69	53.3	43.89	39.72	44.65
May	51.69	63.17	52.55	47.86	53.817	May	55.86	64.51	53.81	49.36	55.885
June	60.9	69.9	60.13	56.33	61.815	June	62	72.83	61.13	57.7	63.415
July	65	76.54	65.51	60.29	66.835	July	70.45	81.58	68.45	64.61	71.272
Aug.	65.96	76.48	66.56	61.77	67.692	Aug.	67.76	76.54	68	63.35	68.912
Sept.	54.9	67.03	59.62	54.73	59.07	Sept.	60.86	71.86	63.03	58.03	63.445
Oct.	46.67	59.77	52.38	47.77	51.647	Oct.	43.32	58.51	51.23	45.67	49.682
Nov.	40.97	49.28	45.33	41.21	43.972	Nov.	36.86	47.79	43.43	38.7	41.695
Dec.	25.96	37.35	33.06	28.77	31.285	Dec.	28.03	36.9	33.54	30	32.117
Mean	43.675	54.555	47.32	42.902	47.113	Mean	44.173	54.96	47.148	42.831	46.277

The hottest and coldest day; the greatest variation in any 24 hours; and range of each month and season, and of the year.

1816.

	Hottest day. d.	Hottest day. °	Coldest day. d.	Coldest day. °	Gr'test change within 24 h'rs. d.	Gr'test change within 24 h'rs. °	Range of each month.
Jan.	22	48	9	1	17	36	47°
Feb.	29	53	15	0	13	28	53
Mar.	28	60	18	1	18	39	59
April	30	85	10	28	10	38	57
May	1	83	14	39	2	40	44
June	23	101	8	41	25	41	60
July	20	89	29	51	10	27	38
Aug.	18	95	28	51	21	35	44
Sept.	3	82	27	35	29	28	47
Oct.	3	75	7	36	4	32	39
Nov.	19	69	29	17	22	26	52
Dec.	27	58	22	2	9	32	56

Range of seasons and year.
Range of the year 101°.
Range of { Winter from 0° to 53° | 53; Spring " 1 to 85 | 84; Summer " 41 to 101 | 60; Autumn " 17 to 83 | 65 }

1817.

	Hottest day. d.	Hottest day. °	Coldest day. d.	Coldest day. °	Gr'test change within 24 h'rs. d.	Gr'test change within 24 h'rs. °	Range of each month
Jan.	4	49	28	−2	27	32	51°
Feb.	22	47	14	−11	11	31	58
Mar.	25	52	20	8	8	26	44
April	17	79	18	29	18	41	50
May	26	80	13	41	27	31	39
June	21	89	1	46	8	30	43
July	18	97	10	56	16	27	41
Aug.	18	92	24	53	24	25	39
Sept.	5	91	30	37	6	26	54
Oct.	6	75	30	25	21	29	50
Nov.	12	67	24	13	26	31	54
Dec.	14	53	22	5	16	26	48

Range of seasons and year.
Range of the year 108°.
Range of { Winter from −11° to 58° | 69°; Spring " 8 to 80 | 72; Summer " 46 to 97 | 51; Autumn " 13 to 91 | 78 }

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

1816. Thermometer at 80° and upwards		1816. Thermometer at 90° and upwards		1817. Thermometer at 80° and upwards		1817. Thermometer at 90° and upwards	
April	1 day	June	4 days	May	1 day	July	4 days
May	4	August	2	June	7	August	1
June	7		—	July	20	Septem.	1
July	10		6	August	10		—
August	12			Septem.	5		6
Septem.	2				—		
	—				43		
	36						

1816: Hottest day June 23, 101°, or 3° above blood heat.

1817: Hottest day July 18, 97°.

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

1816. Thermometer at 32° and under		1816. Thermometer at 0° and under		1817. Thermometer at 32° and under		1817. Thermometer at 0° and under	
January	29 days	Febru'y	1 day	January	28 days	January	3 days
Feb.	25			Feb.	26	Feb'ry	4
March	26			March	18		—
April	3			April	2		7
Novem.	11			October	4		
Decem.	24			Novem.	14		
	—			Decem.	23		
	118				—		
					115		

1816: Coldest day Feb'ry 15, 0°.

1817: Coldest day Febuary 14, —11°.

	Winter.	Spring.	Summer.	Autumn.	Seasons.	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of	27.608	43.264	65.447	51.563	46.97	25.098	44.261	67.866	51.607	47.208

1818. Fifth Series.

Mean of each time of observation, and of each month, at 4 observations per day.

Month.	8 A. M.	Noon.	Sunset.	10 P. M.	Mean.
Jan.	19.46	30.3	25.83	22.25	24.46
Feb.	13.67	27.85	21.09	16.64	19.812
March	32.35	42.93	36.46	31.38	35.78
April	40.1	45.9	40.53	37.9	41.107
May	55.32	63.9	53.5	50.96	55.92
June	68.75	78.73	67.57	64.03	69.77
July	73.6	83.48	71.83	68.54	74.362
Aug.	68.38	80.67	69.22	64.16	70.607
Sept.	58.44	68.8	60.86	56.55	61.162
Oct.	47.54	60.9	53.7	48.38	52.63
Nov.	40.83	50.03	44.73	41.5	44.272
Dec.	21.67	31.9	28.06	23.29	26.23
Mean	45.009	55.449	47.781	43.798	48.009

The hottest and coldest day; the greatest variation in any 24 hours; and the range of each month and season, and of the year.

	Hottest day. d.	°	Coldest day. d.	°	Greatest change within 24 hours. d.	°	Range of each month.
Jan.	2	49	30	−11	30	46	60°
Feb.	28	50	11	−6	27	34	56
March	14	65	6	11	14, 15	24	54
April	25	62	1	31	25	21	31
May	28	89	4	42	24	36	47
June	30	100	8	49	21, 30	28	51
July	12	99	15	58	8,18,31	25	41
Aug.	1	99	17	55	12	28	44
Sept.	3	85	29	44	26	28	41
Oct.	12	74	23	30	24	29	44
Nov.	15	66	25	24	26	24	42
Dec.	6	50	17	3	17	31	47

Range of seasons and year.

Range of the year 111°.

Range of				
Winter	from −11°	to 53°		64°
Spring	"	11	to 89	78
Summer	"	49	to 100	51
Autumn	"	24	to 85	61

Days on which the thermometer was at 80° and upwards, at 90° and upwards, and the hottest day.

Thermometer at 80° and upwards		Thermometer at 90° and upwards	
May	6 days	June	4 days
June	15	July	7
July	22	August	4
August	17		—
September	4		15
	—	Hottest day June 30, 100°.	
	64		

Days on which the thermometer was at 32° and under, at 0° and under, and the coldest day.

Thermometer at 32° and under		Thermometer at 0° and under	
January	29 days		
February	27		
March	17	January	2 days
April	1	February	7
October	2		—
November	5		9
December	29		
	—	Coldest day Jan. 30, —11°.	
	110		

	Winter.	Spring.	Summer.	Autumn.	Seasons.
Mean of	25.463	44.269	71.579	52.688	48.499

Results of the 5 years' Therm. Observations, from 1814 to 1818 inclusive, or of the *fifth* series of observations.

	Mth.	1814	1815	1816	1817	1818	Mean.
Mean of each month in the years respectively, and of those years, and the mean of means.	Jan.	23.96	23.512	25.262	24.02	24.46	24.242
	Feb.	29.64	23.38	27.987	19.99	19.812	24.161
	Mar.	34.332	36.095	30.66	32.25	35.78	33.823
	April	48.732	42.992	45.315	44.65	41.107	44.559
	May	58.582	53.52	53.817	55.885	55.92	55.544
	June	63.58	66.762	61.815	63.415	69.77	65.068
	July	71.765	74.947	66.835	71.272	74.362	71.836
	Aug.	68.507	66.532	67.692	68.912	70.607	68.45
	Sept.	61.772	61.932	59.07	63.445	61.162	61.476
	Oct.	51.11	49.7	51.647	49.682	52.63	50.953
	Nov.	40.81	42.342	43.972	41.695	44.272	42.618
	Dec.	26.577	29.577	31.285	32.117	26.23	29.157
	Mean	48.279	47.607	47.113	47.277	48.009	47.657
Mean of each time of obs. during the year, and mean of means.	8 A.M.	45.205	44.634	43.675	44.173	45.009	44.539
	Noon	55.387	54.953	54.555	54.96	55.449	55.06
	Sunset	48.286	47.563	47.32	47.148	47.781	47.619
	10P.M.	44.244	43.28	42.902	42.831	43.798	43.411
	Mean						*47.657
Mean of each season and mean of means.	Winter	27.536	24.489	27.608	25.098	25.463	26.038
	Spring	47.212	44.202	43.264	44.261	44.269	44.641
	Summer	67.949	69.412	65.447	67.866	71.579	68.45
	Autumn	51.23	51.324	51.563	51.607	52.688	51.682
	Mean	48.482	47.356	46.97	47.208	48.499	47.703

Mean of Spring and Autumn 48°.161. Mean of Winter and Summer 47°.244.

* This mean agrees very nearly with the mean of Sunset. See Dr. Holyoke's Com. Mem. Am. Acad. Vol. ii. Part 1.

N. B. The same remark may be made in this place, as in the corresponding one of the Results of the Second Series.

		1814	1815	1816	1817	1818	Mean.
Annual range.		97°	108°	101°	108°	11[illegible]°	105°
Days on which ther. was at 80° & up. at 90° & up. at 32° & un. 0° & un. & the means.	Days at 80° & up.	39 d.	48 d.	36 d.	43 d.	64 d.	46 days
	Days at 90° & up.	10	15	6	6	15	10.4
	Days at 32° & un.	118	121	118	115	110	116.4
	Days at 0° & un.	4	4	1	7	9	5
Mean of hot & cold days.	Hottest days.	93°	99°	101°	97°	100°	98°
	Coldest days.	—4	—9	0	—11	—11	—7

Hottest and coldest day.

Hottest day June 23, 1816 - 101°

Coldest day, Feb. 14, 1817, and Jan. 13, 1818 } —11°

Range of each Season.

Winter	from	-11°	to	58°	69°
Spring	"	1	to	92	91
Summer	"	41	to	101	60
Autumn	"	13	to	91	78

Greatest Monthly range.

Jan. 1815, June 1816, and January 1818 } 60°

Least Monthly range.

April 1818 - - - - 31°

Greatest range within 24 hours.

April 26, 1814 - - - 47°

Greatest range in 5 years - - - - 112°

Mean of Summers' noon in the 5 years is 77°.314, exceeding Summer heat, as marked on Fahrenheit's thermometer, by 1°.314.

GENERAL RESULTS

of the foregoing Series of Observations for XXI and XXVI years ; also (including the *first* Series, published in the Memoirs of the Amer. Acad. Vol. ii. Part 1.) for XXXIII years—combining the five Series.

	Month	2d Ser.	3d Ser.	4th Ser.	21 Years	5th Ser.	26 Years	1st Ser.	33 Years
Monthly and yearly means, for several periods of time.	Jan.	26.624	26.947	24.236	25.935	24.242	25.609	24.808	25.439
	Feb.	27.997	29.562	27.228	28.262	24.161	27.473	25.07	26.963
	Mar.	36.162	36.189	33.75	35.367	33.823	35.07	36.257	35.321
	April	47.44	46.625	46.325	46.796	44.559	46.366	45.151	46.108
	May	58.291	57.327	55.267	56.961	55.544	56.688	56.871	56.727
	June	68.426	67.803	66.001	67.41	65.068	66.959	67.212	67.013
	July	73.45	72.941	70.486	72.292	71.836	72.204	71.296	72.011
	Aug.	72.856	71.325	69.638	71.273	68.45	70.73	69.751	70.522
	Sept.	63.658	64.14	62.571	63.456	61.476	63.075	61.317	62.702
	Oct.	50.908	51.996	52.285	51.729	50.953	51.58	49.544	51.148
	Nov.	38.744	40	39.364	39.369	42.618	39.994	40.09	40.014
	Dec.	29.403	32.682	31.587	31.224	29.157	30.826	27.775	30.179
	Year	49.496	49.794	48.228	49.172	47.657	48.881	47.928‡	48.678*
Mean of each time of observation &c.	8 A. M.	47.492	47.444	45.566	46.834	44.539	46.392	46.55	46.426
	Noon	56.22	56.633	55.171	56.008	55.06	55.825	54.15	55.47
	Sunset	49.473	49.778	48.088	49.113	47.619	48.825	47.6	48.565
	10 P.M.	44.801	45.323	44.087	44.737	43.411	44.482	43.7	44.316
	Mean	49.496	49.794	48.228	49.173	47.657	48.881	48 ‡	48.694*
Mean of each season &c.	Winter	27.903	29.641	27.752	28.432	26.038	27.971	25.76	27.502
	Spring	47.297	46.713	45.114	46.374	44.641	46.041	46.083	46.05
	Summer	71.577	70 689	68.707	70.324	68.45	69.963	69.38	69.84
	Autumn	51.103	52.045	51.406	51.518	51.682	51.549	50.411	51.308
	Mean	49.47	49.772	48.245	49.162	47.703	48.881	47.908	48.675

Mean of Spring and Autumn, in 33 years, 48°.679, and of Winter and Summer, in the same years, 48°.671.

The numbers with these marks ‡ ‡ and * *, ought to be the same respectively. Hence there was a small inadvertence in the calculations for the *first* series.

		2d Series	3d Series	4th Series	21 Years	5th Series	26 Years	1st Series	33 Years
Means of the greatest changes within 24 hours.		° 36.42	° 35.21	° 40	° 37.21				
Mean number of hot and cold days.	Days at 80° and upwards	d. 56.14	d. 50.57	d. 42.42	d. 49.71	d. 46	d. 48.99	d. 38	d. 46.66
	Days at 90° and upwards	10.85	10.57	6	9.14	10.4	9.38	5.57	8.57
	Days at 32° and under	116	106	118.57	113.52	116.4	114.07	109.28	113.05
	Days at 0° and under	1.57	1.42	2.85	1.94	5	2.53	3.71	2.78
Means of hottest & cold. days.	Mean of hot days	° 95.41	° 96.35	° 94.71	° 95.49	98	° 95.97	° 93.9	° 95.53
	Mean of cold days	—2.85	—0.71	—2.92	—2.16	—7	—3.09	—5·8	—3.66
Hottest & cold't days.	Hottest day	99	100	100	100	101	101	96.5	101
	Coldest day	—10.5	—3	—7	—10.5	—11	—11	—11	-11
Range of Seasons, Months, and Periods of Years.	Greatest Periodical range.	109.5	103	107	110.5	112	112	107.5	112
	Greatest month.rang.	65	67	69	69	60	69	59	69
	Least month.rang.	32	32	31	31	31	31	26‡	26‡
	Range of Winter	fr. -10.5 to 62 72.5	fr.—3 to 63 66	fr. —7 to 66 73	fr. -10.5 to 66 76.5	fr. —11 to 58 69	fr. —11 to 66 77	fr. —11 to 56 67	fr. -11 to 66 77
	Range of Spring	—4 to 95 99	6 to 90 84	1 to 97 96	—4 to 97 101	1 to 92 91	—4 to 97 101	3 to 94 91	—4 to 97 101
	Range of Summer	44 to 99 55	45 to 100 55	45 to 100 55	44 to 100 56	41 to 101 60	41 to 101 60	43 to 96.5 48.5	41 to 101 60
	Range of Autumn	11 to 90 79	16 to 94 78	14 to 93 79	11 to 94 83	13 to 91 78	11 to 94 83	4 to 87 83	11 to 94 83
Means of several Ranges.	Mean Annual range	98.27	97.07	97.64	97.66	105	99.07	99.7	99.2
	Mean grea'st Mth. range	58.78	56.71	55.78	57.09	The Results of the 5th and 1st Series did not embrace these particulars, the 2d, 3d, and 4th Series having been last computed.			
	Mean least Mth. range	33.71	34	34.57	34.09				
	Mean Range of Winter	56.85	58.92	58.5	58.09				
	Mean Range of Spring	76.28	71.28	70.85	72.8				
	Mean Range of Summer	45.41	45.92	44.85	45.39				
	Mean Range of Autumn	68.71	66.14	66.78	67.21				
Greatest changes within 24 hours		41	38	50	50	47	50	41	50

‡ Doubtful—taken from Vol. ii. Part 1. Mem. Amer. Acad. before mentioned.

A Summary and Comparative View of the most important particulars, contained in the foregoing Tables.

Within the period of 26 years, from 1793 to 1818 inclusive.

Mean yearly range of the thermometer - -	48°.881

In this period the mean of the civil year coincided exactly with that of the year, as reckoned by the seasons.

The greatest change within 24 hours - - - -	50°

during the 18 hours preceding 8 A. M. of Feb. 10, 1810, being nearly 3° per hour, in round numbers.

The least monthly range -	31°

a very uniform range, not falling short of 31°, nor exceeding 37°, in 21 years.

Within the period of 33 years, from 1786 to 1818 inclusive.

	Mean yearly range -	48°.678
	Hottest year, 1793 - -	50.96
	Coldest year, 1812 -	45.28
Winter.	Hottest in 1806, mean -	31.995
	Coldest in 1791, mean -	23.383
	Mean range - -	27.502
	Greatest range fr. −11to66	77
Spring.	Hottest in 1793, mean -	50.313
	Coldest in 1812, mean	40.994
	Mean range - -	46.05
	Greatest range fr. —4to97	101
Summer.	Hottest in 1793, mean -	72.615
	Coldest in 1816, mean -	65.447
	Mean range - - -	69.84
	Greatest range fr. 41 to 101	60
Autumn.	Hottest in 1802, mean -	54.627
	Coldest in 1812, mean -	48.963
	Mean range - -	51.308
	Greatest range fr. 11 to 94	83

The *mean* of Spring and Autumn together is the same as that of Winter and Summer together, within 8 thousandth parts of a degree.

The Spring is the most inconstant season, considered with reference to its widest range; but the greatest monthly range was in February 1810, - - 69°

The means of the months indicate January to be the coldest and July to be the hottest month of the year, generally speaking. They, however, shew that February is colder than January in 11 years in 33, or about 1 year in 3, and August hotter than July in 8 years in 33, or about 1 year in 4. But in no instance was February so cold, as the coldest January. Respecting the January of 1802 Dr. Holyoke remarks: "Perhaps the warmest January ever known." The hottest month in this period was August 1798, 75°.777 The coldest month was Jan. 1792 19°.17

Mth.	Hottest.	°	Coldest.	°
Jan.	1802,	34.127	1792,	19.17
Feb.	1797,	32.867	1818,	19.812
Mar.	1805,	39 802	1812,	29.425
April	1800,	50,627	1786,	40.08
May	1793,	62.595	1812,	49.017
June	1793,	71.78	1816,	61.815
July	1805,	75.582	1816,	66.835
Aug.	1798,	75.777	1815,	66.532
Sept.	1801,	66.225	1812,	58.385
Oct.	1809,	57.995	1789,	45.52
Nov.	1788,	44.3	1786,	34.7
Dec.	1794,	40.367	1790,	19.45

Hottest day was June 23, 1816	101°
Coldest days were Feb. 14, 1817 and Jan. 13, 1818, each	—11
Greatest range of the period	112
	days.
The mean days in a year, at or below the freezing point, is	113.05

Of course the season suitable for vegetation is not more than 252 days, or about *two thirds* of the year; and this season is much diminished by *early* and *late* frosts.

In a year the mercury is below zero, on a mean - -	2.78
The mean days, when the thermometer ranges at 80° and above, during a year are	46.66
The mean days of the most intense heat, or at 90° and above, during a year, are - -	8.57

A LETTER

Accompanying the foregoing Tables, addressed to Professor HEDGE, by whom they were communicated.

Boston, March, 1820.

DEAR SIR,

The fatiguing task, you desired me, in the name of Dr. Holyoke, to perform, is at length accomplished. Some inadvertencies in his registers occasioned me the additional labour of casting anew about two hundred thousand figures, in order to render the results as accurate, as possible. Permit me to request you to have the goodness to communicate to the American Academy this humble effort of mine to subserve the interest of the society, if you think it merits that attention, and the business has been executed agreeably to Dr. Holyoke's wish and design.

At the close of my labour it may be proper to state something of the *method*, pursued in drawing up these papers, and to subjoin a short notice of Dr. Holyoke's *Manuscripts*, containing his meteorological observations.

The *method* is almost precisely that, adopted by Dr. Holyoke, in his communication to the American Academy, and published in their Memoirs, Vol. ii. Part 1, in 1793. Those papers contain his observations for a series of seven years. Agreeably to his request, the present papers have been divided into *three* series of seven years each, and *one* of five years. It was thought best by the calculator to find, in that part of the work, headed *General Results*, the means of the *three* complete series, and that of the incomplete *one* (as it may be called) embraced within the term of five years, previously to his combining them with the Results, included in the first series, published in the Memoirs.

The inequality of the series rendered it necessary, in ascer-

taining the different means of 26 and 33 years, to take them for the numbers of those years respectively, and not for *four* or *five* equal series.

In the column of Greatest Change within 24 hours it should be observed, that the day of the month, set down, marks the termination of the change ; and the letters *e, n, s, t,* used in this column, in parentheses, from the year 1804 to 1812 inclusive, denote respectively the times of the observations of the day, viz. 8 A. M. Noon, Sunset, and 10 P. M. which limit that change. It is not, however, to be understood, that a change of temperature from heat to cold, or the contrary, is hereby always indicated ; for the thermometer may continue to rise or fall after such observation ; for instance, the thermometer lowered from noon of the 18th to 8 A. M. of the 20th of July 1804 ; but the number of degrees, which it rises or falls, in a period not exceeding 24 hours, only is indicated. When the period, elapsed between the observations, is just 24 hours, only one letter is used, viz. that, which shews the time of the terminating observation. When two letters are used, the former of them points out the time, when the period of change commences, and the latter, when it terminates : thus, in the year 1804, in the column of Greatest Change within 24 hours, we find March 5th 26° (*tn*), by which is to be understood, that the greatest variation of temperature within any 24 hours, in the month of March of that year, is to be reckoned from 10 P. M. of the 4th day to the Noon of the 5th day of the same, and is 26°. When the greatest change is reckoned from one day to another, it not unfrequently happens, that the lowest temperature of the atmosphere is not expressed, and cannot be expressed, at the times of the observations in the registers ; and of course, that the greatest change *in reality* cannot hereby be ascertained : thus the greatest change within 24 hours, Feb. 10, 1810, reckoning the

temperature at sunrise, would have been found to be 52°, instead of 50°, the number found by using the temperature at 8 A. M. When two or more days give the *same* number of degrees for the greatest change, that was put down in the column, in which the change took place in the least time, whenever this distinction existed.

When the degrees of heat and cold in two or more days in any month happened to be the same, as was not seldom the case, that day, whose *mean* was greatest or least, was put down as the Hottest, or Coldest day, accordingly, in its proper column.

These latter remarks are applicable to the calculations from 1804 to 1812 inclusive, and the results arising from them, this part of the plan not having been adopted till that advanced stage of the business. These 9 years may serve more particularly to show the *rate* of the variation of the temperature.

Dr Holyoke's *Manuscripts,* from which these calculations have been made, are entitled Meteorology. In these he has registered, with almost incredible assiduity, for *one third of a century,* in a perspicuous, neat, and accurate manner, in about twenty columns, the state of the hygrometer, barometer, and thermometer, of the latter both in the house and in the open air, generally four times a day. The same number of times he has recorded in them the direction and force of the winds, and the aspects of the weather, and almost every imaginable atmospheric change, by an appropriate and convenient character, invented by himself, by which he has condensed much interesting matter. He has given here truly *multum in parvo.* The various states of the atmosphere and appearances of the heavens are indicated by about sixty such characters. Besides, these Registers contain a very good Calendar of Flora, and a record of Accidents, embracing many natural phenomena and other events, as parhelia, comets, &c. and whatever may be fairly classed under the head of Meteorology. It

is, also, but justice to the indefatigable perseverance of Dr. Holyoke to state, that during the long period, in which his Registers have been kept, there is scarcely an omission of a single day's observations in several years. It is hoped, that his manuscripts will be deposited in the library of our University, or of some one of our public literary institutions, for the benefit of those, who may wish to consult them.

It should, however, be stated, that in the opinion of some scientific gentlemen, well acquainted with Dr. Holyoke's place of observation, in the open air, [see his communication in the Memoir before referred to] the reflection of the sun from the neighbouring buildings must occasion a sensible augmentation of heat, and that his thermometer, of course, indicates too high a temperature.* Dr. Holyoke would confer a further obligation on the public, if he would take the trouble to ascertain whether this opinion is well founded ; and if so, what correction ought to be applied to the Results of his past Observations.

I am, dear Sir, your friend

and humble servant,

ELISHA CLAP.

Professor Hedge,
of the University in Cambridge.

* With regard to this Dr. Holyoke observes, "The noon observations in this Register are noted one, or perhaps two degrees too high, when the sun shone bright, as the thermometer is then exposed to the heat reflected from the buildings on the north side of the street, which runs nearly east and west : and this circumstance makes some allowance necessary, in determining the precise atmospherical temperature, but does not at all affect the comparison of one year or season with another." *Editors.*

XXIV.

Results of Meteorological Observations, made at Williamstown, Massachusetts.

BY CHESTER DEWEY,

PROFESSOR OF MATHEMATICS AND NATURAL PHILOSOPHY IN WILLIAMS COLLEGE.

Communicated in a letter to Professor Farrar.

1816.

	Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	25.3	27.2	33.8	52.6	63	70.6	63.2	65.5	54.2	52.3	44.7	29.8
2	23.8	24.8	40.5	34.2	44.7	69.3	69	67.7	64.6	54	44.3	13.7
3	13	33	43.9	31.1	56.8	56.4	67.3	70.4	67.3	50.6	57.7	15.8
4	16.5	37	32	43.2	61	56.8	61.9	66.5	62	39.8	65	19.1
5	26.7	23.8	27.5	52.7	60.3	68.8	64.8	65.1	62.6	44.2	55.7	22.2
6	14.1	19	29.1	51.3	56.7	43.4	59.7	63.1	61.2	41.7	39.6	32.8
7	13.3	20.1	31.5	38	48	43.5	55.5	64.5	61.6	34.8	37.8	38.3
8	6.7	5.9	14.3	48.6	41.9	44.8	58	67.2	67.3	45.4	43.7	34.2
9	11.1	10.5	6.7	49.9	44.3	48.6	54.5	65.8	57.6	57.3	37.9	20.5
10	10.3	14.9	15.4	29	50.8	44.1	62.8	65.7	51.5	61.9	35.8	22.9
11	9.7	20.5	22.7	35.4	49.1	54.8	68	71.1	50.2	52.7	30.8	32.1
12	19.8	29.8	32	37.6	54.2	65.8	65.1	69.6	52.5	46	26.6	42.2
13	8.4	12.1	32.7	35.8	55	62.4	65.8	67.1	51.4	49.1	28.4	40
14	2.7	0.7	35.1	30.6	39.8	69.4	67	66.3	56.4	54.6	34.1	28.8
15	8.6	—.8	16	31.5	46.1	64.3	71.5	74.2	60.5	56.2	43	25
16	21.7	8.2	28.9	31.6	45.5	62.2	79.1	73.5	56.5	53.4	36.9	11.5
17	44.7	23.4	18	32.9	40	62.4	59.2	68.2	51.2	40.9	52.5	21.4
18	32	35.1	8.2	32.9	45	60.3	58.5	71.2	56.7	38.8	61.5	39
19	34.4	33	21.5	39.6	56.3	73.4	69.2	73.5	57.3	40.6	63.5	15.9
20	21.4	33.4	33.9	44.4	58.3	56.6	71.8	63.1	62.3	50.3	60.9	19
21	30.3	32.7	30.5	40.6	65.4	64.9	66	51.6	47.6	58.3	31.1	18.5
22	31.4	32.5	18.9	42.1	67.3	74.7	71.1	59.8	51.5	57.6	21.4	13.8
23	32.7	37.1	31.4	44.8	50	76	73	61.9	56.7	49.7	31.8	22.9
24	40.9	33.8	37.1	42.1	52.7	77.9	66.6	66.6	58	42.5	32.4	34.7
25	24.4	40.2	32.5	47.3	44.3	56.7	60.4	61.3	51.9	39.9	23.6	44.1
26	31.1	33.8	49	50.7	53	61.8	62.5	63.3	40.4	48	23.1	42.2
27	11.6	29.7	48.4	53.2	58	62.7	63.9	57.2	40.1	41.7	35.5	44
28	19.6	37.1	43	54.3	59.7	56.8	60	50.2	42.9	40.8	25.2	32.5
29	25.6	40.2	27.1	58.3	47	57.4	59.8	54.1	46.2	49.9	27.4	32.7
30	13.1		30.4	63.8	58	58.4	62	64	50	55	40	18.7
31	26.8		37.9		65		66.7	62.2		53.1		30.7
Mean.	21.03	25.15	29.35	42.68	52.81	60.84	64.64	64.89	55.02	48.42	39.73	27.71
Highest.	53	48	67	80	78	90	90	87	85	73.2	71	50
Lowest.	-13.3	-8	-6.3	26.2	33	35	43	37.5	25.3	27.8	5 5	1
*	30.6	29	32.7	35.5	32.3	34.5	30	34	38.7	36	28	28
	4	11	27	30	3	11	2	29	28	1	26	24
Inches of water.	1.75	2.38	2.17	1.63	3.55	3.67	2.13	1.69	1.10	2.33	2.71	0.87

* This line contains the greatest daily range of the thermometer, and the following line the day of the month when it occurred.

The observations were made with a thermometer suspended about 6 feet from the ground, upon the north side of a house, and protected from the direct rays of the sun. Hours of observation 7 A. M. and 2 and 9 P. M. The above abstract contains the mean temperature of each day of the year, deduced from the three observations; the mean of each month; the highest and lowest temperature of each month; the greatest daily range of each month, and the day on which it happened; and the quantity of rain and snow in each month.

Mean temperature for the year 44 35.

" of the highest and lowest in each month 44.95.

Quantity of water 25.98 inches.

Winds N. W. 279 times; S. 95; S. E. 74; and S. W. 71; through the day N. W. 157.

It is a common opinion, that the mean temperature of the place may be obtained from taking the mean temperature of its springs. The situation of the springs, however, must make some difference, even when there are no chemical combinations which affect their temperature. The following is the temperature of three springs, deduced from observations, taken each month in the year. The 1st 48°.39; 2d 47°.1; 3d 46°.11. The 1st is near a rise of land of 64 feet, and its temperature varied only 1°.25 during the year. The others are under very small elevations and appear to be much more affected by the falling of rain and the melting of snow. The temperature of the 2d varied 5°, that of the 3d, 18° during the year. The drought affected the last spring so much that its mean temperature ought not perhaps to be relied upon.

Frosts are extremely rare here in either of the summer months; but this year there was frost in each of them. June 5th, at noon,

the temperature was at 83°—a thunder shower had cooled the atmosphere 14° at 2 P. M. June 6th the temperature about 44° through the day—snowed several times. On the mountain to the west, and in Cheshire, Windsor, and Peru, at the S. E. the ground was white with snow—travellers complained of the severity of the N. W. wind and snow storm. June 7th, no frost, but the ground frozen, and water frozen in many places from $\frac{1}{10}$th to $\frac{1}{8}$th inch thick. Moist earth was frozen half an inch thick, and could be raised from round Indian corn, the corn slipping through and standing unhurt. June 8th, some ice was seen in the morning—earth very little frozen—no frost—wind still strong and piercing from the N. W. Cucumbers and other vegetables nearly destroyed. June 9th, less wind, and some warmer. June 10th, severe frost—Indian corn, beans, cucumbers, &c. cut down. June 11th, severe frost in the morning—temperature at 2 P. M. 70°.5. Ten days after the frost, the trees on the sides of the hills presented for miles the appearance of having been scorched. June 29th and 30th, some frost. July 9th, frost, which killed parts of cucumbers. August 22d, cucumbers killed by the frost. August 29th, severe frost. Some fields of Indian corn were killed on the low grounds, while that on the higher was unhurt.

Very little Indian corn became ripe in this region. Of that which was cut up at the roots immediately after being killed, and made to stand upright in small collections, about one half became fit for food. But that which was not cut up did not ripen.

1817.

Months.	Highest.	Lowest.	Highest mean.	Lowest mean.	Range in a day. Greatest	Range in a day. Least.	Mean of the month.	Quantity of water.
January	46.5	-4.6	40	4.15	26.5	4	20.81	1.972
February	40.8	-20	38.2	-10.53	23	3.3	15.10	2.169
March	53	0	39.7	15.10	32.2	1.2	28.55	1.975
April	80.3	23	65.9	32.63	32.3	3.5	43.77	1.465
May	81.8	34	66.5	39.57	40	5	54.31	2.585
June	84	36	69.1	45.67	33	5	59.57	7.189
July	91.1	50	77.1	59.70	31	8	67.40	2.814
August	85.3	44	76 1	47	32	4	66.47	6.477
Septem.	83.2	31.5	73.1	39.5	32	6.5	58.68	4.358
October	73.3	18	60.1	28.9	33	4	45.06	2.039
Novem.	71.8	11.4	64.8	16.9	27	6	38.79	2.920
Decem.	54.8	-6	44.9	0.17	27	4	27.02	2.394

Mean temperature of the year - - 43.79
" of highest and lowest in the months 43.48
" of do. and do. means do. 43.09

Greatest heat 92.7 July 18th about 3 P. M.

Quantity of water, rain and snow, 38.357 inches.

Winds N. W. 260; S. W. 99; S. E. 91; S. 77; W. 14; N. E. 2; and E. 1; and, through the day, N. W. 153.

Mean state of the thermometer for February 5th, —8.75; 11th, 0.23; 14th, as given in the table —10.53; 15th —10.2; 16th, —3.9. Thermometer during the *cold Friday* of 1810, did not, on the whole, stand so low as it did on the above 14th of February. The greatest cold ever observed here, — 28, which happened in December 1796.

The temperature of the three springs, mentioned in the observations of last year, and also of Green river, was noted three times a month. The result is not materially different from that above given. Mean temperature of the 1st spring 48.33; 2d, 47.35; 3d, 45.65; and of Green river, 47.35. The 1st varied only $1\frac{1}{2}$° during the year; the 2d, 7°; the 3d, 21°.4; and the river, 42°, or from 32° to 74°.

An attempt to ascertain the mean temperature by twenty-four observations in the day, and the three

1816	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V
Mar. 25	30.33	30.16	29.50	29.50	29.75	33.50	33.50	33.25	37.33	37.50	38.66	38.75	40	38.53	39.75	39.50	39	37
" 26	26	26.50	31	32	33.50	36	38.25	40.33	44.33	44.75	51.50	56	61	64	65	63.75	60.75	59
" 27	34.33	33.25	32.75	31.75	30	30	30.25	34.25	40.25	47.25	53.25	59.50	55.66	63.66	67	66	63.25	59
" 28	39.75	39.67	39.25	39.16	39.50	40.50	42.67	48.49	49	48.25	47.50	48.50	49.66	47	45.67	44	43	41.
" 29	33.75	33.50	32.67	31	30.75	30	30	31.25	26.50	26.75	28	27	27.25	28	29.25	30.67	31.20	30.
Mean	32.83	32.61	33.03	32.68	32.70	34	34.93	37.42	39.48	40.90	43.78	45.95	46.71	48.20	49.33	48.78	47.44	45.

Mean of 7 A. M. and 2 P. M. = 43.37
" 9 P. M. - - = 33.28

Mean at 12 and 12 = 39.74
" 1 " 1 = 40.40
" 2 " 2 = 41.08
" 3 " 3 = 40.73
" 6 " 6 = 38.29

Mean at 6 A. M. and 2 and 9 P. M. = 39.18
" 5 " 2 10 " = 38.61
" 6 " 1 9 " = 38.80
" 6 " 1 10 " = 38.23
" 8 " 1 10 " = 39.75
" 7 " 2 10 " = 40.12

1816	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V
April 1	42.75	43.33	44.25	45.50	48.16	47.84	49.84	51.67	53.20	53.33	55	55.25	53.80	54.20	55	55	54	53.
" 2	45.50	43.33	42.20	40.80	40.40	37.25	37.25	38	40.25	37.53	32	33	32	35.50	36.67	36.33	36.25	34.
" 3	27.33	25.67	23.25	22.33	22.25	22.75	22	27	28	29.25	31.67	33	35.75	37.75	40	42	4[illegible].25	41.
" 4	25.25	28	27	25.75	26	27	27.75	31	37	42	46.75	49	52	54.16	56	57	57.25	56
" 5	40	39.50	40.67	38.83	36.80	36	33	38.67	43.33	48.67	50	62.50	64	66.33	65	62	60	56.
Mean	36.16	35.97	35.47	34.64	34.72	34.17	39.97	37.27	40.35	42.12	43.08	46.55	47.51	49.59	50.53	50.46	49.95	48.

Mean of 7 A. M. and 2 P. M. = 43.86
" 9 P. M. - = 40.52

Mean at 12 and 12 = 41.83
" 1 " 1 = 42.78
" 2 " 2 = 43.00
" 3 " 3 = 42.50
" 6 " 6 = 40.28

Mean at 6 A. M. and 2 and 9 P. M. = 41.67
" 6 " 2 10 " = 41.46
" 6 " 1 9 " = 41.36
" 6 " 1 10 " = 41.15
" 8 " 1 10 " = 43.27
" 7 " 2 10 " = 42.56

1816	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V
July 23	65.83	65.25	63.50	62.80	62.16	62	64	67.50	71	74.50	76	80.66	82	83.80	85.45	74	74	75.
" 24	64	61.75	59	58.50	57	58	59	61.67	68.25	70.[illegible]0	74.20	73.80	78	77.33	77.20	78	77	74.
" 25	58.70	58.25	56.20	55.80	54.50	54.75	54.33	55.90	59.60	62.80	61.20	64	66.50	67.30	68.60	69.75	70.80	70
" 26	50.33	49.50	47.25	46	44.66	44.40	48	53	58	61.50	62.30	66.80	68.66	70.75	73	74.25	75.30	74.
" 27	55.10	54	53.10	53.17	52.80	53.17	53.50	57	60.25	64	66	66	69.25	71.40	75.80	76	73.25	72
Mean	58.79	57.55	55.81	55.25	54.22	54.46	55.77	59.01	63.42	66.60	67.94	70.[illegible]	72.88	74.12	76.01	74.40	74.07	73.

Mean of 7 A. M. and 2 P. M. = 67.51
" at 9 P. M. - - = 60.91

Mean at 12 and 12 = 65.83
" 1 " 1 = 65.83
" 2 " 2 = 65.91
" 3 " 3 = 65.82
" 6 " 6 = 63.32

Mean at 6 A. M. and 2 and 9 P. M. = 64.23
" 6 " 2 10 " = 63.59
" 6 " 1 9 " = 63.60
" 6 " 1 10 " = 62.96
" 8 " 1 10 " = 65.51
" 7 " 2 10 " = 64.67

1816	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V
Oct. 28	32.80	31.10	30.75	29.75	30	29	28	27.80	30.70	36	40.40	47.75	51.80	52.60	55.50	53.20	52.84	48.
" 29	37.75	38.50	39.50	39.40	38.50	38	37	37.16	40	46.40	52	58	60.30	61.83	63	64.20	60.16	56.
" 30	46.16	45.33	41.50	40.66	41.83	42.50	45	45.75	49.30	56.40	59	62	63.60	62.60	63	60.20	59	58
" 31	53.70	52.50	53.20	54	53	52.20	51.30	51.84	53.80	58	59.50	63.50	62.84	65	67	66	57.50	49.
Nov. 1	36.40	37.30	38	38.80	39.50	40.20	40	39.50	41	43.84	45.20	46.20	49.75	51.16	50	49.80	47.40	45
Mean	41.36	40.95	40.59	40.52	40.56	40.38	40.26	40.41	42.96	48.13	51.22	55.49	57.6[illegible]	58.64	59.70	58.68	55.38	51.

Mean of 7 A. M. and 2 P. M. = 50.08
" 9 P. M. - - = 45.98

Mean at 12 and 12 = 49.51
" 1 " 1 = 49.79
" 2 " 2 = 50.14
3 " 3 = 49.60
6 " 6 = 44.84

Mean at 6 A. M. and 2 and 9 P. M. = 48.65
" 6 " 2 10 " = 48.61
" 6 " 1 9 " = 48.29
" 6 " 1 10 " = 48.26
" 8 " 1 10 " = 49.16
" 7 " 2 10 " = 49.33

1817	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V
Jan. 6	24.20	24	24	24.20	24.40	24.50	25	26	27	28.50	31.50	35	36.80	38.10	39.80	39.40	38.30	38
" 13	6	4.25	4	5.10	5.75	6	6.10	6.30	7.20	9.70	13	19	19.60	21.50	22	20.10	18	16.5
" 14	13.50	10.25	10	12.25	13	9.50	6	3.85	3	5	7.50	10.17	12.30	13	13.50	13.20	11.40	9
" 15	8	9	9	9.80	10	10.60	11.50	12	13.50	16.20	20.50	24.20	25.25	26.20	26	26.25	26	22.3
" 16	23.8	24	23.2	23	22	22	22	22	22	22.90	24.30	26.60	26.90	26.70	27	26	25	23.7
" 17	22.6	22.6	22.3	22	21.60	19	18	16	18	22.50	29	30	29.60	30	29.50	30	29.60	29.2
" 23	−1	−2	−2	−2.50	−3.20	−3.80	−5	−4.60	−3.75	2	7.30	11.40	15	17	15.80	14.40	13.40	12.5
" 31	5.50	6.70	7	7.60	8.10	8.90	9.66	10.10	12.20	16.60	18.50	22.10	23.33	24	26	19.50	16.80	14.5
Feb. 5	−3	−4.60	−6.30	−7.70	−9.40	−11	−12.60	−14.33	−11.50	−7.50	−5	−4	−2	0	−0.70	−1	−1.10	−3.3
" 6	−11.5	−10	−8	−4.50	−3	−1.10	1.2[illegible]	3	5.20	8.80	12.80	20	24.60	26	26.50	25	24.20	23.2
Mean	8.81	8.42	8.32	8.92	8.92	8.46	8.19	8.03	9.28	12.47	15.94	19.45	21.14	22.25	22.54	21.2	20.16	18.5

Mean at 7 A. M. and 2 P. M = 15.28
" 9 P. M. - - = 16.16

Mean at 12 and 12 = 14.97
" 1 " 1 = 15.33
" 2 " 2 = 15.43
" 3 " 3 = 15.10
" 6 " 6 = 13.15

Mean at 6 A. M. and 2 and 9 P. M. = 15.63
" 6 " 2 10 " = 15.66
" 6 " 1 9 " = 15.53
" 6 " 1 10 " = 15.53
" 8 " 1 10 " = 15.93
" 7 " 2 10 " = 15.61

The *mean* of *nine* P. M. is much nearer the *mean* of 7 A. M. and 2 P. M. in winter than in summer. This is doubtless the reason that the mean of the 24 observations so nearly coincides with that of 7 A. M. and 2 and 9 P. M. at all seasons. Had the observations been more frequent, the mean temperature would probably be found to be somewhat nearer that of these three hours, than it appears to be in this result.

Of the *thirty days*, the
Mean of 24 observations - - - - . =41
" 7 A. M. and 2 and 9 P. M. - - =42
" highest and lowest - - - =41
" do. do. means - - - =42
" 8 and 1 and 6* - - - - - =45
" about sunrise and sunset - - - - =40

* Hours proposed by the Philosophical Society of New York.

twenty-four observations in the day, and the three hours in the day which will give nearly the mean temperature.

VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	Sum of the 24 observ.	Mean of 24 observ.	Mean of 7 A. M. & 2 & 9 P. M.	Mean of highest & low.	Range.
37.33	37.50	38.66	38.75	40	38.33	39.75	39.50	39	37	34	30	26.20	24.50	23.50	24	797.48	33.23	32.50	31.75	16.5
44.33	44.75	51.50	56	61	64	65	63.75	60.75	59	52.66	47	45	41.66	38.33	37	1095.31	45.64	49	45.50	39
40.25	47.25	53.25	59.50	55.66	63.66	67	66	65.25	59	54.66	51	48.75	44	41.66	39.75	1111.22	46.30	48.42	48.50	37
49	48.25	47.50	48.50	49.66	47	45.67	44	43	41.67	39.66	37	36.33	35.50	34.67	34	1009.91	42.08	43.06	41.83	15.6
26.50	26.75	28	27	27.25	28	29.25	30.67	31.20	30.25	27.25	24.50	22.50	20.75	19.66	19.84	672.29	28.01	27.08	26.71	14
39.48	40.90	43.78	45.95	46.71	48.20	49.33	48.78	47.44	45.38	41.65	37.90	35.75	33.28	31.56	30.92	39.05	39.05	40.01	38.86	

at 12 and 12 = 39.74
1 " 1 = 40.40
2 " 2 = 41.08
3 " 3 = 40.73
6 " 6 = 38.29

Mean at 6 A. M. and 2 and 9 P. M. = 39.18
" 6 " 2 10 " = 38.61
" 6 " 1 9 " = 38.80
" 6 " 1 10 " = 38.23
" 8 " 1 10 " = 39.75
" 7 " 2 10 " = 40.12

Mean at 7 A. M. and 1 and 9 P. M. = 39.30
" 7 " 1 10 " = 39.06
" 8 " 2 10 " = 40.12
" 8 " 1 9 " = 40.32
" 8 " noon and 9 " = 39.82
" 8 " " 10 " = 39.25

Mean at 9 A. M. and 1 and 10 P. M. = 40.22
" 9 " noon and 10 " = 39.72
" 8 " 1 6* " = 43.08
Mean of highest and lowest means = 40.12
" about sunrise and sunset = 38.29

VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	Sum of the 24 observ.	Mean of 24 observ.	Mean of 7 A. M. & 2 & 9 P. M.	Mean of highest & low.	Range.
3.20	53.33	55	55.25	53.80	54.20	55	55	54	53.80	54.33	53.75	53	51.33	49.75	47.25	1225.33	51.05	52.66	49	12.5
0.25	37.33	32	33	32	35.50	36.67	36.33	36.25	34.75	32.66	30.75	29.67	28	27.25	27.50	854.64	35.61	34.22	36.35	17
8	29.25	31.67	33	35.75	37.75	40	42	4[illegible].25	41.67	38	33	27	26.25	26.33	26	730 50	30.44	31.08	32.12	20
7	42	46.75	49	52	54.16	56	57	57.25	56	52.75	47	44	42.67	41.33	38.84	991.50	41.31	43.22	41.21	32
3.33	48.67	50	62.50	64	66.33	65	62	60	56.50	55.20	54.20	53.50	54.33	54.75	55	1208.78	50.37	52.66	49.66	33
0.35	42.12	43.08	46.55	47.51	49.59	50.53	50.46	49.95	48.54	46.59	43.74	41.43	40.52	39.88	34.92	41.76	41.76	42.77	41.67	

at 12 and 12 = 41.83
1 " 1 = 42.78
2 " 2 = 43.00
3 " 3 = 42.50
6 " 6 = 40.28

Mean at 6 A. M. and 2 and 9 P. M. = 41.67
" 6 " 2 10 " = 41.46
" 6 " 1 9 " = 41.36
" 6 " 1 10 " = 41.15
" 8 " 1 10 " = 43.27
" 7 " 2 10 " = 42.56

Mean at 7 A. M. and 1 and 9 P. M. = 42.46
" 7 " 1 10 " = 42.25
" 8 " 2 10 " = 43.59
" 8 " 1 9 " = 43.59
" 8 " noon and 9 " = 42.79
" 8 " " 10 " = 42.88

Mean at 9 A. M. and 1 and 10 P. M. = 43.86
" 9 " noon and 10 " = 42.58
" 8 " 1 6 " = 45.51
Mean of highest and lowest means = 42.97
" about sunrise and sunset = 40.00

VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	Sum of the 24 observ.	Mean of 24 observ.	Mean of 7 A. M. & 2 & 9 P. M.	Mean of highest & low.	Range.
1	74.50	76	80.66	82	83.80	85.45	74	74	75.20	75	70.66	68	66.25	65	63.60	1696 16	70.67	73.07	73.72	23.4
8.25	70.[illegible]0	74.20	73.80	78	77.33	77.20	78	77	74.67	71	66.50	62.75	61	59.50	59	1607.32	66.97	66.62	67.50	21
9.60	62.80	61.20	64	66.50	67.30	68.60	69.75	70.80	70	69.40	65.75	61.25	56.80	52.50	52	1466.68	61.11	60.43	61.40	18.8
8	61.50	62.30	66.80	68.66	70.75	73	74.25	75.30	74.50	72.75	68.50	65.60	61.50	59.67	56.67	1452.89	60.54	62.50	59.85	30.9
0.25	64	66	66	69.25	71.40	75.80	76	73.25	72	68.25	68	60.15	59	58.25	59.50	1498.94	62.46	63.93	64.40	23.2
6.42	66.60	67.94	70.[illegible]	72.88	74.12	76.01	74.40	74.07	73.27	70.88	67.88	63.55	60.91	58.98	58.16	64.35	64.35	65.31	65.37	

t 12 and 12 = 65.83
1 " 1 = 65.83
2 " 2 = 65.91
3 " 3 = 65.82
6 " 6 = 63.32

Mean at 6 A. M. and 2 and 9 P. M. = 64.23
" 6 " 2 10 " = 63.59
" 6 " 1 9 " = 63.60
" 6 " 1 10 " = 62.96
" 8 " 1 10 " = 65.51
" 7 " 2 10 " = 64.67

Mean at 7 A. M. and 1 and 9 P. M. = 64.68
" 7 " 1 10 " = 64.04
" 8 " 2 10 " = 66.07
" 8 " 1 9 " = 66.07
" 8 " noon and 9 " = 65.74
" 8 " " 10 " = 65.51

Mean at 9 A. M. and 1 and 10 P. M. = 66.57
" 9 " noon and 10 " = 65.91
" 8 " 1 6 " = 69.47
Mean of highest and lowest means = 65.11
" about sunrise and sunset = 66.17

VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	Sum of the 24 observ.	Mean of 24 observ.	Mean of 7 A. M. & 2 & 9 P. M.	Mean of highest & low.	Range.
0.70	36	40.40	47.75	51.80	52.60	55.50	53.20	52.84	48.60	46	41	40.20	39	39	38.[illegible]0	952.59	39.69	40.77	41.65	27.7
0	46.40	52	58	60.30	61.83	63	64.20	60.16	56.16	53.40	52	50.40	49.50	49.16	49	1171.32	48.81	49.89	50.60	27.5
9.30	56.40	59	62	63.60	62.60	63	60.20	59	58	57.50	57.20	56.50	56.20	56.66	56.16	1282.05	53.42	54.98	52.13	22.9
3.80	58	59.50	63.50	62.84	65	67	66	57.50	49.60	46	42.60	40.84	40.50	40	37.50	1271.92	53	53.11	52.25	29.5
1	43.84	45.20	46.20	49.75	51.16	50	49.80	47.40	45	44.25	44	44.70	44.70	44.60	44	1045.30	43.55	44.73	43.78	14.7
2.96	48.13	51.22	55.49	57.6[illegible]	58.64	59.70	58.68	55.38	51.47	49.43	47.36	46 55	45.98	45.88	45.09	47.69	47.69	48.69	48.08	

t 12 and 12 = 49.51
1 " 1 = 49.79
2 " 2 = 50.14
3 " 3 = 49.60
6 " 6 = 44.84

Mean at 6 A. M. and 2 and 9 P. M. = 48.65
" 6 " 2 10 " = 48.61
" 6 " 1 9 " = 48.29
" 6 " 1 10 " = 48.26
" 8 " 1 10 " = 49.16
" 7 " 2 10 " = 49.33

Mean at 7 A. M. and 1 and 9 P. M. = 45.01
" 7 " 1 10 " = 44.98
" 8 " 2 10 " = 49.51
" 8 " 1 9 " = 49.16
" 8 " noon and 9 " = 48.87
" 8 " " 10 " = 48.83

Mean at 9 A. M. and 1 and 10 P. M. = 50.88
" 9 " noon and 10 " = 50.56
" 8 " 1 6 " = 50.33
Mean of highest and lowest means = 49.98
" about sunrise and sunset = 45.94

VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	Sum of the 24 observ.	Mean of 24 observ.	Mean of 7 A. M. & 2 & 9 P. M.	Mean of highest & low.	Range.
	28.50	31.50	35	36.80	38.10	39.80	39.40	38.30	38	38.50	38.50	38.80	38.60	38.80	39	780.90	32.[illegible]4	34.80	31.90	14.8
.20	9.70	13	19	19.60	21.50	22	20.10	18	16.50	16.60	16.20	16	16	15.70	15	305.60	12.73	14.77	13	18
	5	7.50	10.17	12.30	13	13.50	13.20	11.40	9	6.30	4.50	3.83	4.66	6.70	7.50	210	8.75	7.34	8.25	10.5
.50	16.20	20.50	24.20	25.25	26.20	26	26.25	26	22.30	22.20	22.60	23	24	26	24.20	448.30	18.68	20.66	17.62	17.25
	22.90	24.30	26.60	26.90	26.70	27	26	25	23.75	23	23	23	22.83	22.80	22.60	570.38	23.76	23.94	24.50	5
	22.50	29	30	29.60	30	29.50	30	29.60	29.20	30.60	33.50	32.80	31.10	31	32	632.50	26.35	25.53	24 40	16.8
.75	2	7.30	11.40	15	17	15.80	14.40	13.40	12.50	19	19	20	18.10	18	18	193.05	8.04	9.77	7.50	22
.20	16.60	18.50	22.10	23.33	24	26	19.50	16.80	14.50	11.20	9.67	9.60	8.60	8.20	5.50	309.86	12.91	14.90	15.75	20.5
.50	−7.50	−5	−4	−2	0	−0.70	−1	−1.10	−3.33	−6.50	−8.60	−10	−11.25	−11.50	−12.67	−165.58	−6.89	−8.76	−7.16	14.33
.20	8.80	12.80	20	24.60	26	26.50	25	24.20	23.20	20.20	16.33	12.40	9	7	7	234.13	9.76	12.83	7.50	38
.28	12.47	15.94	19.45	21.14	22.25	22.54	21.2	20.16	18.56	18.11	17 47	16.94	16.16	16.27	16.81	14 66	14.66	15.58	14.35	

12 and 12 = 14.97
1 " 1 = 15.33
2 " 2 = 15.43
3 " 3 = 15.10
6 " 6 = 13.15

Mean at 6 A. M. and 2 and 9 P. M. = 15.63
" 6 " 2 10 " = 15.66
" 6 " 1 9 " = 15.53
" 6 " 1 10 " = 15.53
" 8 " 1 10 " = 15.93
" 7 " 2 10 " = 15.61

Mean at 7 A. M. and 1 and 9 P. M. = 15.48
" 7 " 1 10 " = 15.52
" 8 " 2 10 " = 16.03
" 8 " 1 9 " = 15.89
" 8 " noon and 9 " = 15.53
" 8 " " 10 " = 15.56

Mean at 9 A. M. and 1 and 10 P. M. = 16.99
" 9 " noon and 10 " = 16.63
" 8 " 1 6 " = 16.55
Mean of highest and lowest means = 15.28
" about sunrise and sunset = 14.01

nd
the
M.
ore
ne-
re-

Of the *thirty days*, the
Mean of 24 observations - - - - . = 41.50
" 7 A. M. and 2 and 9 P. M. - - - = 42.47
" highest and lowest - - - - = 41.66
" do. do. means - - - - = 42.69
" 8 and 1 and 6* - - - - - = 45.00
" about sunrise and sunset - - - - - = 40.88

Of the five successive days in January, the
Mean of 24 observations - - - - - = 18.05
" 7 A. M. and 2 and 9 P. M. - - - = 18.45
" 6 " 2 9 " - - - - = 18.68
" highest and lowest - - - - = 17.55

	Mean of 24 observ.	Mean of 7 & 2 & 9	Mean of highest & lowest.
Feb. 15, 17, 18, and 19, gave	9. 32	10.25	8.07

* Hours proposed by the Philosophical Society of New York.

1818.

Months.	Highest.	Lowest.	Mean of the month.	Mean of Barom.	Winds.					Water.
					N. W.	S. E.	S. W.	S.	NW all day	Inch.
January	43°	-18	20.26	29.20	25	11	6	6	15	2.294
February	49	-22.5	14.94	29.14	22	6	7	6	12	1.716
March	64.5	-3	31.23	29.26	20	5	6	9	14	3.701
April	65	27	39.09	28.91	25	11	3	8	15	4.522
May	88	36	53.59	28.98	21	11	3	5	12	4.289
June	94.5	49	68.50	29.10	18	8	9	10	6	4.307
July	92.2	53.5	71.25	29.13	21	6	8	14	9	5.133
August	89	45	65.95	29.23	24	6	12	6	11	2.043
Septem.	84	33	55.60	29.11	22	6	3	5	15	3.606
October	73	21.3	48.11	29.19	22	7	6	11	14	0.282
Novem.	65.7	21	39.75	29.16	22	6	7	9	13	2.178
Decem.	42	-8	22.03	29.25	27	7	1	6	18	1.042

The first *four* columns of wind show the number of times the wind has been from those points at the regular hour of observation, and the last column the number of days in which the wind has been N. W. through the day.

Mean temperature of the year 44°.19.

" of the highest and lowest temperature 45°.17.

" height of Barometer 29.14 inches.

Dividing the winds at the three daily observations into 100 parts, about 59 are N. W.; 14, S. E.; 10, S. W.; 13, S.; 1, E.; 2, W.; 1, N. E.

Zodiacal light observed several evenings at the end of February and beginning of March.

Aurora Borealis observed May 23 and 28; June 6 to 10th; September 24 and 25th; and October 6 and 7th.

Mean temperature of 1818 a little less than that of 1816.

" of 1816, 1817, and 1818, 44°.11.

" temperature of *three springs* for two years 48°.31, 47°.22, and 45°.83; the mean of which is 47°.12. This is nearly the mean, according to Kirwan's theory, allowing the elevation of this place to be 1000 feet above the tide water of the Hudson at Troy, and allowing 1° of reduction from the standard temperature for an elevation of thirty feet in a mile.

1819.

Months.	Highest. °	Lowest.	Highest mean of any day.	Lowest mean of any day.	Mean of the month.	Mean of Baromet. inches.	Water. inches.	Winds. N.W.	S. W.	S.	S. E.	E.	W.	NW all day
January	55.2	-5.5	45.3	1.3	28.14	29.30	1.212	51	13	14	11	1	1	11
February	55	3.5	47.2	12.4	27.73	29.12	2.251	54	7	11	8	1	1	10
March	52	-1.4	40.3	11.2	25.86	29.08	3.958	48	6	20	17	0	2	9
April	73.5	17.5	53.4	25.5	42.19	29.17	2.342	63	2	11	10	1	0	17
May	86.5	35.5	68.7	41.9	55.30	29.05	2.946	40	6	14	27	2NE	0	9
June	92	51	79.3	57.0	67.22	29.17	2.697	40	7	31	7	0	0	9
July	93.3	48.5	80.8	57.5	70.31	29.33	6.311	45	5	38	5	0	1	10
August	94	43.7	80.7	53.7	68.99	29.27	2.983	63	6	15	10	0	0	18
Septem.	90.5	43.2	77.5	50.4	64.01	29.20	3.755	26	11	15	22	1	4	5
October	79.3	28.0	68.1	29.8	46.31	29.17	1.148	44	12	29	4	0	2	10
Novem.	72	16	56.1	22.6	38.21	29.25	0.995	45	5	19	15	0	2	12
Decem.	50	-5.5	40.3	2.5	25.07	29.06	1.565	67	5	11	3	1	4	18
Sum	893.3	274.5	747.7	365.8	559.34	350.17	32.163	586	85	228	137	5	17	138
Mean	74.44	22.88	62.31	30.48	46.61	29.18								

Mean temperature of the year, - - - - 46°.61.

" of highest and lowest in each month - - 48.66.

" of greatest and least mean temp. of each month 46.39.

" height of the barometer - - - 29.18 inch.

Quantity of rain and snow - - - - 32.163 "

Dividing the winds, at the three daily observations, into 100 parts, there have been, from the N. W. 55; S. W. 8; S. 21; S. E. 13; E. $\frac{4}{10}$; W. 1.6; and N. E. $\frac{2}{10}$. Wind all day from N. W. 138 days.

Aurora Borealis was seen fourteen evenings, six of which were in October.

XXV.

On the extraordinary darkness that was observed in some parts of the United States and Canada, in the month of Nov. 1819.

BY FREDERICK HALL,

PROFESSOR OF MATHEMATICS AND NATURAL PHILOSOPHY IN MIDDLEBURY COLLEGE, VERMONT.

THIS phenomenon first attracted my attention on the morning of the 9th of November 1819. I rose at a quarter before seven, and found it much darker than it ordinarily is in the evening at the time of full moon. It snowed fast for about an hour ; this was succeeded by a moderate rain, which continued most of the day. Being occupied, I took no further notice of the uncommon darkness till about nine o'clock. At this time, the obscurity, instead of diminishing, had considerably increased. The thermometer stood at 34°. A strong, steady, but not violent wind blew from the south.

The darkness was so great, that a person, when sitting by a window, could not see to read a book, in small type, without serious inconvenience. Several of the students in the college studied the whole day by candlelight. A number of the mechanics in this village were unable to carry on their work without the assistance of lamps.

The sky exhibited a pale yellowish-white aspect, which, in some degree, resembled the evening twilight a few moments before it disappears. Indeed we had little else but twilight through the day ; and such too, as takes place when the sun is five or six de-

grees below the horizon. The colour of objects was very remarkable. Every thing I beheld wore a dull, smoky, melancholy appearance. The paper, on which I was writing, had the same yellowish-white hue as the heavens. The fowls showed that peculiar restlessness that was remarked in them during the total eclipse of the sun in 1806. Some of them retired to roost. The cocks crowed several hours incessantly, as they do at the dawning of day.

At 3 P. M. the sky brightened up a little, but in the evening the darkness became more extraordinary. A person could not discern his hand, held directly before his eyes. It was next to impossible for a person to find his way even in streets where he had been long accustomed to walk.

The sun was concealed from our view, nearly the whole time, from Monday evening to Friday morning. It did occasionally appear, but was always of a deep blood-red colour ; and the apparent magnitude was at least one third larger than usual. This was very striking on Friday, about nine in the morning. A dense, yellow vapour was then passing slowly over its enlarged disc. The spectacle was viewed by many with astonishment.

The darkness was not confined to this immediate vicinity. It was as great seventy miles west (in the state of New York) as at this place. And here I beg leave to insert an extract of a letter, on this subject, from Noadiah Moore, Esq. of Champlain, N. Y. a well informed and highly respectable gentleman.

"The darkness was first noticed on the night of the 6th Nov. when the day closing with a hazy atmosphere, the night became so exceedingly dark as to render the sense of sight wholly useless. The horse and his rider were in equal uncertainty. The moon, though near the full, produced no sensible change as it rose. Even

the faint *profile* of the landscape, so important a guide to the benighted traveller, was lost in intense obscurity. The atmosphere continued to be clouded by dense vapours until the 9th ; when the darkness greatly increased. A light snow covered the ground. It blew a strong gale from the south. The clouds, from which fine drops of rain were contiually descending, resembled the pitchy blackness of the smoke of a furnace ; they moved in a wild and hurried manner through the heavens, and, at times, seemed to be closing down upon the earth. Several claps of distant thunder were heard, and in a town adjoining, a heavy shower ensued.

"The water caught in this shower was observed to be much discoloured. A quantity caught in a clean vessel, exposed in a situation where it fell directly from the heavens, was preserved for many days in a corked phial, and did not wholly deposit its colouring matter. In appearance, it was not unlike water impregnated with soot. As to the degree of darkness which prevailed, it may be observed, that writing, reading, or needlework could not be properly performed without candles ; indeed, candles were used during most of the day in many of the houses and workshops. Towards evening it brightened up a little, but night brought darkness tangible."

The darkness was observed throughout the northern portion of this state, and in several parts of Canada. At Montpelier, about forty miles northeast of this place, it is said to have been greater than it was here. A gentleman, from that town, informed me that the darkness there was so great, that the speaker of the House of Representatives could not distinguish the countenances of the members, so as to determine who was addressing him. The same gentleman added, that where he stopped to dine, he was obliged to make use of a candle to distinguish the different kinds of food which were placed before him.

In the small quantity of water, which fell from the atmosphere, I did not observe any extraordinary colour, or smell, or taste. It is stated in *Le Courier du Bas-Canada*, "that the water was of a black colour, as if it had been impregnated with a large proportion of soot; and that several persons, who had tasted it, discovered the taste of soot. This colour the water retained a considerable time." I have read remarks of a similar kind in the newspapers from various parts of New England. Had the fall of water here been more copious, I should probably have noticed the peculiarity above described.

The appearance of the heavens during the late period of darkness was very much like that which is frequently occasioned by extensive fires in the woods. An effect, similar in kind, but far inferior in degree, was produced a few years since by the fires, which raged several weeks, and consumed most of the underwood on the Green mountains opposite this place. The darkness observed at that time was very considerable, and the sky was of a pale yellowish-red aspect.

The cause assigned by Dr. Williams,* for the uncommon darkness of 1780, is perhaps the most satisfactory which could be given. But in the present case, no similar cause can be supposed, at least in New England. No great fires were destroying our woodlands. It was too late in the season. The combustible matter of the forests was not sufficiently dry.

The darkness of 1780 occurred in May after a long period of dry weather; that of 1819, in November, without being preceded by any unusual drought, especially in this part of the country. The former lasted only thirteen or fourteen hours; the latter nearly a week.

* Memoirs of the Amer. Acad. vol. i. p. 234.

The cause of this phenomenon, whatever it may be, is undoubtedly to be sought at a considerable distance to the south of New England. Many persons in this vicinity, as well as myself, observed, that when the wind blew most powerfully from a southerly quarter, it brought with it a vast quantity of smoke, or of something much resembling it; and that the sky was then the darkest; that when the wind shifted, and blew a short time in any other direction, the atmosphere was in a degree cleared of this smoky matter. During the time the darkness lasted there was for the most part a pretty strong wind from the south. On Friday morning it changed to the west, and continued to blow for some time from that quarter. The unusual obscurity gradually disappeared, and objects, both in the heavens and upon the earth, soon assumed their ordinary aspect.

Since writing the above, I have seen an article in the "Missionary," of the twelfth of November—a very respectable paper—printed at Mount Zion, Hancock Co. Georgia, relating to this phenomenon. It is stated, that "the atmosphere had been very smoky for about a fortnight preceding; so much so, that it had literally intercepted the rays of the sun at noon during a part of this time, and seriously affected the eyes." "It is doubtless," added the writer, "occasioned by great fires in the Indian territories. The wind has blown almost invariably from that direction for some time."

That the late darkness had its origin in some of our most southern states, or in the territories belonging to them can, I think, hardly be questioned. It is by no means improbable that it was occasioned by fires, running on those immense *prairies* that furnish annually such vast quantities of combustible materials. We are told that these prairies "are covered with a coarse kind of grass,

which, before the country is settled in their vicinity, grows to the height of six or seven feet."* This vegetation, another writer observes, "becomes sufficiently dry to burn during the long dry season, called the *Indian Summer;* which commences usually in October, and continues a month and a half or two months, during which the vegetation is killed by the frost and dried by the sun; the wet prairies are also dried, and before the season has expired, the grass is perfectly combustible."† In order the more easily to take their game, and to facilitate travelling from one hunting ground to another, the Indians, we are informed, occasionally set fire to the Prairies "towards the close of the Indian summer."

* See Atwater's Letters to Professor Silliman on the Prairies of the West, published in "The American Journal of Science," v. i. p. 116.

† See R. W. Wells' communication on prairies, published in the same work, v. i. p. 334.

XXVI.

On an Inscription from the Columbarium of the Freedmen and Slaves of Livia Augusta.

BY EDWARD EVERETT,

ELIOT PROFESSOR OF GREEK LITERATURE IN HARVARD UNIVERSITY.

I HAD the good fortune while in Rome, in the winter of 1818—1819, to procure an inscription, hitherto inedited, from the *Columbarium*, or sepulchre, of the slaves and freedmen of Livia Augusta, the wife of Augustus. Large collections of inscriptions from this remarkable monument are in the hands of the learned, and all of them, that had been discovered at the time of their respective publication, may be found in the following works; viz:

Monumentum, sive Columbarium libertorum et servorum Liviæ Augustæ et Cæsarum, Romæ dectectum, in via Appia Anno CIƆIƆCCXXVII, ab Antonio Francisco Gorio, presbytero baptisterii Florentini descriptum, et xx ære incisis tabulis illustratum, adjectis notis Cl. V. Antonii Mariæ Salvinii. Florentiæ, 1727. fol.

Camera ed Inscrizioni Sepulcrali de' liberti, servi ed ufficiali della Casa di Augusto, Scoperte nella via Appia, ed illustrate con le annotazione di Monsignor Francisco Bianchini, Veronese; l'anno 1727.

Besides these two classical works, one hundred and seventy-three of these inscriptions are found in the Appendix to Hessel's preface to his edition of the Inscriptions of Gudius, having been communicated to Hessel by Duker, who had received them from

George Waddel.* In the year 1731, a series of engravings was published by Lorenzo Philip de Rossi, from drawings by Ghezzi, intending to convey a more accurate representation of these antiquities, than is furnished by the plates in the works of Gori or Bianchini. This work contains no copy at large of the inscriptions found in this monument.†

No one, who has consulted these works, needs to be informed of the great light thrown upon the branch of sepulchral antiquities, as well as on the domestic economy of the Romans, by the discovery of this monument; nor will refuse his assent to the remark of Gori, who, having enumerated the various subjects illustrated by this discovery, adds—"quam plurima, quæ ad hoc tempus eruditis incognita fuere, quæque non mediocriter illustrant Romanæ historiæ monumenta, per tot secula tenebris damnata, in dias luminis oras nunc emergunt et prodeunt."‡ The inscription, which I was fortunate enough to procure from this monument, being neither in the collections of Gori, or Bianchini, or Hessel, (though the first of these contains three hundred and four and the second two hundred and twenty) and being therefore inedited, I am desirous of laying it before the Academy; while the rarity, or perhaps I may say the total want of similar monuments of classical

* Jam triennium aut quadrennium est, quum Via Appia, non longe ab urbe, monumenta libertorum et servorum domus Augusti detecta sunt; quæ partim a docto Viro *W. Dundass*, partim etiam a se descripta, Georgius Waddel, vir humanitate perpolitus, cum Dukero nostro communicavit, et ille mecum.—*Gudii Antiquæ Inscriptiones; Hesselii præf. Append.*

† Camere Sepolcrali de' liberti e servi di Livia Augusta ed' Altri Cesari—come anche altri Sepolcri ultimamente ritrovati fuori della porta Capena, disegnati secondo le regole della architettura dal Cavaliere P. L. Ghezzi, date in luce da Lorenzo F. de Rossi, 1731. Roma. fol.

‡ Preface to the work of which the title is given above, p. xiii.

antiquity, in our country, and the consequent want of excitement in the pursuit of the study of this branch of literature, have emboldened me to trespass on the attention of the Academy with a few additional remarks connected with the subject.

It is well known, that as early as the laws of the XII tables, it was forbidden to bury the dead within the walls of Rome.* The practice of crowding the dead into church yards, and into the vaults of churches, had its origin in superstitious notions of the necessity of being deposited in consecrated ground. The same superstition has occasionally led to the importation of holy land from Palestine, to serve as the foundation of churches. Of this there is an instance in Amsterdam of a church erected in the fifteenth century. The Greeks and Romans, as well as other nations of antiquity, placed the sepulchres of the deceased without the walls of the cities, and by the sides of the public roads; whence perhaps the source of the address often made to the *Viator* in monumental inscription. This was not only favorable to public health, but was thought to have a happy operation on the character of the community, in constantly recalling the memory of the illustrious dead. Themistocles said that the tombs in the Ceramicus would not let him sleep; and Cicero alludes in a similar connexion to the tombs of the Scipios, the Servilli, and the Metelli on the Appian Way.

The tombs thus mentioned by Cicero are still recognized. That of Cecilia Metella is one of the most beautiful monuments of antiquity remaining at Rome. That of the Scipios, discovered in 1780,

* Cf. Gothofredi Fontes quatuor juris civilis tab. x. and p. 252. It was also forbidden by Theodosius, to bury within the walls at Constantinople:—a practice still observed by the Turks in that city, though the population has extended itself so widely in the suburbs, that the burial places in Pera are surrounded with habitations.

whether for the renown of the illustrious family whose ashes it contained, or the light, which is thrown on palæography by the inscriptions discovered in it, is one of the most important remains of Roman antiquity. One cannot but lament, while he admits the necessity which dictated it, the transportation of the venerable sarcophagi, which it inclosed, to the collection of the Vatican. Not wantonly, however, to wound the feelings of those who visit the spot where the Scipios were entombed, the places of the ancient sarcophagi have been supplied in the tomb, by exact imitations representing, in size, in the quality of the stone, and the inscriptions on them, the monuments, which, for their own preservation have been transported to the Papal museum.*

The Columbarium of the freedmen and slaves of the Augustan house, without sharing that interest which is awakened by the tombs of the Scipios and the Servilii, is still a curious monument of antiquity. I shall translate from Bianchini an account of its discovery and situation.—" In leaving Rome at what is commonly called the gate of St. Sebastian's from one of the seven primary churches, to which the Appian Way conducts you from said gate, after having proceeded above half a mile, you reach, on the left, a church called at the present day *Domine quo Vadis*, from the vision, by which St. Peter was warned back to Rome to suffer martyrdom."

* * * * *

"Eight hundred feet beyond the first milestone you arrive at the gate of a vineyard, on the left hand, within which, at the right hand, stands the sepulchre of the *freedmen and domestics of Livia and of the Augustan house*. The owner of the vineyard is Joseph Benci, a Roman; who, having understood that there were reasons

* The ashes and bones themselves were transferred to Padua, and deposited, by a nobleman there, in a monument, with appropriate inscriptions.

to hope for the discovery, under the ruins of the ancient edifice, of something precious, which would reimburse him for the expense of the excavations, and for the injury which it would do to the vineyard, accepted a proposal made him for the undertaking of the work."

"The work was begun in November 1725, but nothing of importance was found till January 1726, when an entrance was made into a hall, filled, not indeed with such treasures as was expected, but with several ranges of cinerary urns, each urn with its inscription, from which great light is thrown on the study of antiquity. Several pieces of marble were also found, with various sculptures in *bas relief*; and the pavement was an entire work in Mosaic. But the haste, with which the work was done, and the sparing scale with respect to expense, contributed much to the destruction of the building and its ornaments."*

Such is the account of the discovery of this monument. At present it is quite dilapidated. All the fragments of marble have disappeared, as they would naturally be among the first objects transported to the museums, or sold. The tablets of marble containing the inscriptions are all gone, the fronts of many of the little niches, in which the urns were deposited, broken down, and a few only of the urns left in their places. The Columbarium consisted of three large apartments, one of which serves at present as a wine vault. Though much decayed, its original form and arrangement can be plainly seen, and pots partly filled with ashes are still in some of the niches. It is probable that this dilapidation commenced at early periods ; and that every thing valuable or thought valuable was plundered from this, as from the other ancient monuments, by barbarous invaders, or contending barbarous factions

* Bianchini, p. v.—vii.

at home.* Such a gradual destruction will account for the scattering, in the adjacent fields and vineyards, of many of the inscribed tablets, which the Columbarium contained; one of which has furnished the occasion of this memoir.

With regard to the word *Columbarium*, by which these and other similar sepulchral monuments are designated, it is well known that its primitive meaning, is that of a *pigeon house*, and a *pigeon hole*. From the similarity of the form, the *niches*, in the walls of the sepulchre, nearly closed in front, in which the cinerary urns were deposited, were called Columbaria, or pigeon holes; and thence the word was transferred to the sepulchre itself. This meaning is not recognized by the lexicographers; but is ascertained from an inscription preserved by Fabretti, and quoted by Gori as follows:—

EX. TESTAMENTO. Q
ERUCI. MONTANI. LEGATUM.
C. QUINTIO. BATHYLLO. COLUM
BARI. *ITUM. AMBITUM.* DEBETUR.†

In this inscription, *Columbarium* cannot well be understood but of a place of burial, admitting of a path to it, and round it, and of course could not have been applied to a small niche in a wall. It was in these small niches that were deposited the urns to contain the ashes of the common freedmen and slaves, often two and two, the urns for instance of husband and wife, in the same niche. These urns wese built into the wall, and the ashes of course poured into them. Over the aperture, by which this was done, a small marble tablet was let into the wall, on which the name and office of

*For a very learned and judicious dissertation on the causes of the destruction of the works of ancient art, in Rome, see the third volume of the Italian translation of Winckleman, by the antiquary *Fea*.

† Gori, p. 53. Fabretti, Inscr. Antiq. c. iv. p. 320. n. 432 and c. x. p. 703. n. 247.

the person, whose ashes were enclosed in the urn, were designated: and often for the prevention of mistake, the number and position of the niche accurately designated. In the royal museum, at Dresden, the apartment devoted to the reception of cinerary urns and other sepulchral antiquities, is fitted up so as to imitate the interior of an ancient Columbarium;—with this important difference, however, necessarily resulting perhaps from the nature of a museum, as a place of display, viz. that the *fronts* of the niches are left open, thus exposing the urns to view; whereas in antiquity they were closed, all but an aperture large enough to pour the ashes through, from the principle, that ran alike through all their institutions and manners, of avoiding, as much as possible, the sight or the name of death.

The inscription, to which I wish at present to call the attention of the Academy, is on a tablet of fine white marble, 17½ inches long and 6 high. The inscription consists of three lines, extremely well cut; the letters, in the first line, being nearly an inch and a half in height, those in the second and third line something less. It is as follows;

DIONYSIUS. LIVIAE.
ROGATOR. DECURIO.
C. JULIUS C. ET. SPONSAE. L. FELIX.

That is, Dionysius Liviæ Rogator*um* Decurio, C*aius* Julius, C*aii* et Sponsæ L*ibertus*, Felix.

There are one or two points, in this inscription, which require illustration. The first is the office, which the individual is said to have filled, Decurion of the Rogators of Livia. What the office of Rogator was does not appear. It occurs on two other inscrip-

tions found in this *Columbarium*, and numbered xxxiii. and xxxiv. of Gori. The first is

EROS. AUG. L. ROGATOR. LIVIA. LEZBIA.

Eros. Augustæ Libertus, Rogator. Livia Lezbia.

Gori remarks on this inscription, that neither in Gruter nor his continuator Reinesius, is any mention made of the office of *Rogator*, in the household of the empress. He quotes, however, an inscription preserved by Fabretti, p. 74, in which the office of *Rogator* is mentioned, but without any adjunct, by which its nature can be ascertained. Fabretti, to explain the term in the inscription alluded to, remarks that *Rogator* was the officer who, at the *comitia*, carried the box to the citizens, to receive the tablets, on which their suffrages were inscribed, as is shown by Sigonius de Comit. Rom. l. i. c. 3. This is the signification adopted for the word by Bianchini, in the inscription on Eros just quoted. Gori, more judiciously thinks, that the Rogator of Livia might have corresponded to what would be called *master of requests*, in a modern royal household, the person whose business it was to present petitions to the empress. He adds, however, the remark, that Rogator might possibly have been the officer, whose duty it was to apply to those, of whom the empress wished any thing; a signification too vague, and an office too general and undefined to be admitted. He attempts to illustrate it by a quotation from Suetonius, which, however, proves nothing. (Sueton. Aug. Vita. c. xl.)

That the first interpretation is the correct one, is rendered more probable by the other inscription, marked xxxiv. in Gori, where *Rogator* occurs, connected with another title, viz. *ab officiis admissionum*, which would correspond to our designation of *Chamberlain* or *Usher*.

The lexicographers mention an additional signification of Rogator, viz. an officer in the theatres, whose business it was to collect dresses and decorations for the use of the stage. And Ficoroni, in his work on masks (de Personis Scenicis), produces three inscriptions where it is used in this sense. There is an inscription in Muratori, where the *Rogator of the theatre* is mentioned, but he is there expressly called Rogator a Scæna; as he would also probably have been in the inscription before us. Moreover one is not prepared to find so large a number of theatrical officers of this kind, in the household of the empress, as would be implied by a Decurion of Rogators.

With regard to the last line of the inscription, I am unable, from my limited acquaintance with monuments of this kind, to determine, whether another individual be spoken of,—or whether Dionysius, the Decurion of the Rogators of Livia be the same person who is called, in the last line, Caius Julius Felix, the freedman of Caius and his wife. If they be the same person, it is perhaps remarkable that he should have four names, nor does it appear particularly in what order these four names are to be read. If it be a different person, who is mentioned in the last line, he is left without any designation of office, or any thing to indicate his connexion with the Dionysius of the two first lines. Similar cases, however, are found among these inscriptions, and that, of which I have already quoted a part, is one, Eros Augustæ Libertus Rogator; Livia Lezbia; in which the female mentioned is doubtless the wife of Eros.

With regard to the Caius, of whom and of his wife Caius Julius Felix in the last line, is said to be the freedman, it may deserve to be specified, that he was the son of Marcus Agrippa and Julia, and adopted with his brother Lucius, by Augustus. Returning from

Armenia to Rome, he died at Lamyra in Lycia, and his ashes were transported to Rome, where they arrived at the moment that Livia was employed in dedicating a splendid triumphal arch to his brother Lucius.

XXVII.

An account of some Greek Manuscripts, procured at Constantinople in 1819, and now belonging to the Library of the University at Cambridge.

BY EDWARD EVERETT,

ELIOT PROFESSOR OF GREEK LITERATURE IN HARVARD UNIVERSITY.

SCARCE any object more engages the attention of the travellers in Greece, than the search for classical manuscripts; and the valuable discoveries, that are still made, serve—notwithstanding the degree to which the libraries throughout that country have been ransacked—to keep the hopes of the scholar awake. It is well known that perhaps the most valuable manuscript of Plato, which we possess, was brought from the island of Patmos by Dr. Clarke, a few years ago. We may excuse the severity with which those Greeks, who feel for the literary degradation of their native country, speak of the removal of such manuscripts from the convents and schools in Greece, where they are still preserved. But it cannot of course be doubted that the cause of literature at large authorizes the European traveller to avail himself of the ignorance and insensibility of the Greek priests and monks, and to induce them to sell those manuscripts which can only become generally useful, by being taken from their present places of deposit, and brought to regions, where they will be collated and made known to the world.*

* Koray expresses himself with severity on this subject, in the prolegomena to his second book of Homer. He closes a note alluding to the removal of the

I omitted no opportunity of searching for Greek manuscripts in the libraries of the religious houses, which I visited in Greece, particularly those of Megaspelion in the Morea and of Meteora in Thessaly. The former library is the most ample; but the latter has been least explored by travellers, since it is but of late years that their usual route has gone so far to the north, as to include this portion of Thessaly. In neither of these libraries did I find any thing of interest. Just on leaving Constantinople, however, I heard from Mr. Cartwright, the British consul general, of a few Greek manuscripts, belonging to the family of a Greek prince in decay, which were offered for sale. As I had made arrangements for leaving the city the next morning, I had no opportunity of examining more than one, which happened to be in Mr. Cartwright's possession, and I availed myself of his good offices in procuring that, and the others offered with them, and safely shipping them to London. They are now in the library of the University at Cambridge; and being the only Greek manuscripts, of which I have heard in this country, I have thought that a brief description of them might be acceptable to the Academy.

I. The first is a quarto manuscript, containing sixteen discourses of Gregory of Nazianzen. They are all in the printed editions of his works. The manuscript, like all the others which were procured with it, is on parchment. It is in good preservation,

manuscript of Plato from Patmos, in the following words—"Τὸν δὲ λογιώτατον Κλάρκιον συμβουλεύω ἂν θέλῃ νὰ τὸν συγχωρήσωσι καὶ οἱ ὁμογενεῖς του τὴν ἄτοπον ἐξομολόγησιν, καὶ οἱ γραικοὶ τὴν ἀδικίαν, νὰ ἐκδώσῃ διὰ τῶν τύπων ὅσα ἔλαβεν ἀπὸ τὴν Πάτμον ἀντίγραφα, νὰ πωλήσῃ τὰ τυπωμένα, καὶ νὰ πεμψῃ τὴν τιμὴν εἰς τὸ σχολεῖον τῆς Πάτμου." σελ ιδ'. This valuable manuscript of Plato, with the others collected by Dr. Clarke, has been purchased by the University of Oxford, and a collation of it published by Mr. Gaisford.

but coarsely written, and does not appear to be older than the thirteenth or fourteenth century.

II. A large quarto Evangelistary; that is, the four gospels arranged in the lessons, as they are read in the Greek church. The New Testament was divided into sections by the ancient church, and all the sections taken from the gospels were called *the gospel* τὸ εὐαγγέλιον, and all from the Acts and epistles *the Apostle* ὁ ἀπόστολος. The manuscripts thus divided are usually called in general *Lectionaries*; those of the gospels alone, *Evangelistaries*. It might be supposed that as these lectionaries were the public authorized copies used in the churches, they would present a more fixed and constant text than the private manuscripts; which might partake of a more critical character. This, however, has not been observed to be the case; though instead of thinking with Wetstein,* that this circumstance diminishes their critical value, I should regard it in the opposite light. A great part of this manuscript is apparently of the thirteenth century; but some portions written to supply the place of lost leaves are much more recent.

III. An Evangelistary, and an Apostolos forming together the whole New Testament, divided into the lessons of the church. This manuscript is in two quarto volumes of sizes somewhat unequal, beautifully written; the rubrics and titles in gold letters. As it has never been collated for any edition of the New Testament, it may be interesting to the Academy to remark, that the celebrated text, Acts xx. 28. stands in it, "the church of the

* Cum primum multa Evangelistaria Anno 1715 in Bibliotheca Colbertina vidissem, avide ad illa cum editis conferenda me accingi, sperans me inventurum constantem et publice receptam in Ecclesia Græca lectionem. At eventus expectationi meæ non respondet, nam et ipsos inter se atque a nostris editionibus non raro dissentire deprehendi. *Wetstenii proleg.* p. 62.

Lord and God;" and that 1 John v. 7. is wanting in this, as in all the other ancient Greek manuscripts. It is probably of the twelfth century.

IV. A quarto manuscript containing the Psalter in the Septuagint version. It is beautifully written and preserved. It also contains the explanations of the title of the Psalms by Psellus, and a Menologia or Greek Missal, with astronomical tables and diagrams for finding Easter. It is apparently of the thirteenth century.

V. A fragment containing a few leaves of a large quarto size of high antiquity. These leaves served as a sort of covering to the manuscript No. 2. when it came into my possession, and from the appearance of the manuscript, I had the mortification of concluding, that other leaves of the same *codex* had been torn off and lost. It is written in uncial letters, and from its close resemblance to a manuscript, of which Woide has given a specimen in the prolegomena to his edition of the Alexandrian *codex*, to which manuscript he affixes the date of 995, there is every reason to conclude that the fragments before us are as old as this. On what grounds Woide attaches so precise a date to the aforesaid manuscript, I am not aware: he probably found a date in the manuscript itself. But without this, the character in which the fragments in question are written, like those in Woide's specimen, is such as to authorize us in assuming an antiquity as great as the tenth century. Nor are there many manuscripts that go back to an earlier date either of sacred or profane writings. These fragments belong also to a lectionary, and comprise the following portions of the gospels. *Matthew* iv. 25; v. 1, 13, 36, 46. *John* xiv. 30, 31; xv. 1—4; xvi. 19, 24, 33; vi. 5; xvii. 18; xvii. 2, 14; xiv. 29.

VI. A very neat and well written quarto manuscript containing the chronicle of Michal Glycas, who lived probably in the twelfth century. Both the age and country of this writer have been the subject of more controversy than the intrinsic merits of his work authorize. Leo Allatius, a learned Greek himself, has been followed by several European critics in the opinion, that Glycas flourished in the fifteenth century, after the capture of Constantinople. This opinion rests on the circumstance, that among the epistles ascribed to Glycas are three addressed to Constantine Paleologus, the last of the Christian emperors, who perished A. D. 1453. But as the annals of Glycas terminate at the year 1118, and there is no proof that the epistles, which bear his name, are not a miscellaneous collection by various authors, it has been inferred with greater probability by Cave, Dupin, Fabricius and others, that Glycas flourished in the twelfth century. Whether he were a native of Sicily or Constantinople is also a matter of question, and debated at length by Lami.*

The chronicle, of which the manuscript in question is a copy, relates the history of the world, from the creation down to the death of Alexius Comnenus in 1118. A part of the work containing the history from Julius Cæsar to Constantine the Great, was published with a Latin version by Meursius at Leyden in 1618, with this title—" *Theodori Metochitæ* historiæ Romanæ a Julio Cæsare ad Constantinum liber singularis, Gr. ac Lat. edidit cum notis suis &c." I am unacquainted with the circumstances which led Meursius to ascribe this work to Theodore Metochita. Leunclavius or Löwenklau published a Latin version of the whole work in 1572 with a continuation down to the capture of Constantinople

* In the deliciæ Eruditorum. Fabricii Biblioth. Græc. Ed. Harlesii. Tom. vii. p. 468.

by the Turks. In 1660, the entire work in Greek, with the version of Leunclavius, the whole revised and corrected from several manuscripts, was published by Labbe, and from this edition it was incorporated into the collection of the Byzantine historians. It constitutes the ninth volume of that collection, in the Venetian edition. It has been long since observed that the text of Labbe's edition of Glycas is both incorrect and incomplete; and the present manuscript, as far I have had opportunity to collate it, furnishes the means of many emendations in the received text of this author. The appearance of the manuscript would seem alone to prove, that the author of the work múst have lived at an earlier age than that which some of the learned have ascribed to him. It has all the characteristics of a manuscript of the twelfth or thirteenth century.

To this brief account of Greek manuscripts, I beg leave to add a notice of a manuscript of a Latin translation of the politics, rhetoric, and larger morals of Aristotle, which I procured at Florence, and which is now deposited in the College library. It is well written, in black letter, on parchment, but of no very great antiquity. It belonged originally to Petrus Victorius, an editor and commentator of Aristotle, and afterwards to the convent of Santa Maria Novella, at Florence. The following note on the title page will show that it is not without value:—" Hic est liber ille veteris translationis nonnullorum librorum Aristotelis, cujus sæpe mentionem fecit Petrus Victorius; præcipue autem in Epistola ad studiosos artis dicendi, in commentarios suos in tres libros Aristotelis de arte dicendi, affirmat hujus auxilio se usum fuisse, in corrigendis libris illis temporum ac librariorum injuria deformatis. Cum enim hæc translatio, *multis antea seculis confecta fuerit,* quo tempore libri Aristotelis integriores emendatioresque erant,

auctorque ipsius, quicumque ille fuerit, negotium cum multa fide administraverit, ac ne verborum quidem ordinem variaverit, inde se cognovisse Victorius narrat quam scripturam in suo exemplari ille habuerit. Hoc autem cum in librum inciderim, adnotandum hic censui ego Franciscus Victorius Petri Nepos, ut hoc etiam nomine liber custodi Bibliothecæ et iis qui illum legent commendatus sit, sententiamque meam laudaturos studiosos bonarum artium speravi, cum vir maximi ingenii atque admirabilis doctrinæ, frater Vincentius Civitella, illam approbaverit."—The encomium pronounced on this manuscript by Victorius, is entitled to consideration from the character of this critic. He was among the best Greek scholars of the sixteenth century. Buhle calls him "Aristotelicæ philosophiæ omninoque Græcarum et Latinarum literarum scientia inter æquales insignis, etsi contemtim de eo senserit Scaligerus."* The opinion of Scaliger concerning Victorius is pronounced as follows. "Petrus Victorius bon homme mais *longus*. On faisoit en Italie extreme estat de Victorius, mais ce n'est pas grand cas : il escrit de miserables lettres *cum magnis ambagibus*." Victorius devoted his life to letters, and wrote commentaries on the works of Aristotle at the age of eighty five.†

* Buhle Opera Arist. tom. i. p. 347.

† Harlesii Introd. in histor. Ling. Græc. i. 452.

CATALOGUE

OF BOOKS AND OTHER ARTICLES PRESENTED TO THE ACADEMY SINCE THE PUBLICATION OF THE THIRD VOLUME OF MEMOIRS.

PRESENTS.	DONORS.
Notice des Fossiles du Governement de Moscou, 2 parts 4to. 1809, 1810.	Hon. J. Q. Adams.
Boston Gazette for 1813.	Editor.
Independent Chronicle " "	"
New England Palladium. " "	"
Boston Patriot. " "	"
Weekly Messenger " "	"
Columbian Centinel. " "	"
Boston Daily Advertiser. " "	"
A sermon occasioned by the death of the Rev. Thomas Barnard, D. D. by John Prince, LL. D.	John Prince, LL. D.
An Oration occasioned by the death of John Warren, M. D. by Josiah Bartlett, M. D.	Josiah Bartlett, M. D.
Observations on Contagious Diseases, by David Hosack, M. D. F. L. S. New York, 1815. 4to.	David Hosack, M. D.
A specimen of Stalactites from a cave in the vicinity of Lake Erie.	Charles Stearns, D. D.
Mémoires de l'Académie Impériale des Sciences de St. Petersburg, tom. i. St. Petersbourg, 1809. 4to.	Imperial Academy of Sciences of St. Petersburg.
Transactions of the Literary and Philosophical Society of New York, vol. i. New York, 1815. 4to.	Literary and Philosophical Society of New York.
Analyse des Travaux de la Societé Royale Veterinaire, Copenhague, 1815. 4to.	Royal Veterinary Society of Copenhagen.
Commentationes Societatis Regiæ Scientiarum Gottingensis Recentiores, vol. iii. Gottingæ, 1806, 4to.	Royal Society of Gottingen.
Kongl Vetenskaps Academiens Handlingar för Åren 1812, 1813, 1814. Stockholm, 8vo.	Royal Academy of Sciences at Stockholm.
Essay on British Cottage Architecture, by James Malton. London, 1797. 4to.	William Paine, M. D.
Journal de Physique for May and June, 1815. Paris, 1815, 4to.	
Mémoire sur les Fluxions de Poitrine.	J. G. Cogswell, Esq.
Mémoire sur le Cautère par Louis Valentine.	" "
Inaugural Address, delivered in the chapel of the University at Cambridge, by John Gorham, M. D Boston, 1817. 8vo.	John Gorham, M. D.

PRESENTS.	DONORS.
Inaugural Address, delivered in the chapel of the University at Cambridge, by Jacob Bigelow, M. D. Boston, 1817. 8vo.	Jacob Bigelow, M. D.
Mémoires de l'Académie Impériale des Sciences de St. Petersbourg. Tome II. 1813.	Imperial Academy of Sciences of St. Petersburg.
Proposals for an Insane Hospital, by George Parkman, M. D. Boston. 8vo.	George Parkman, M. D.
Critical Review for 1815.	
Letters and Papers of the Bath and West of England Agricultural Society. Vols. 6—13, inclusive. Bath, 1782—1814. 8vo.	Bath and West of England Agricultural Society.
Flora Batava, Nos. 39, 40.	His Majesty the king of the Netherlands.
Transactions of the Royal Irish Academy, 1787—1815. 11 vols. 4to. Dublin.	Royal Irish Academy.
Philosophichal Transactions of the Royal Society of London. Parts 1 & 2 for 1817. London, 1817, 4to.	Royal Society of London.
Astronomical Observations made at the Royal Observatory at Greenwich for the years 1811, 1812, 1813, 1814 and 1815, 5 vols. London, 1812—1817. folio.	President and Council of the Royal Society of London.
Mémoires de l'Académie Impériale des Sciences de St. Petersbourg. Tom. IV. V. 1815, 1816. St. Petersburg, 4to.	Imperial Academy of Sciences of St. Petersburg.
A brass four inch Theodolite.	E. A. Holyoke, M. D.
Transactions of the American Philosophical Society held at Philadelphia for promoting useful knowledge. Vol. I. New Series. Philadelphia, 1818, 4to.	American Philosophical Society.
The Massachusetts Spy from the year 1784 to 1808. 13 vols. Worcester, folio.	Isaiah Thomas, Esq.
Philosophical Transactions of the Royal Society of London. Parts 1 & 2, for 1818. London 1818, 4to.	Royal Society of London.
Mémoires de l'Académie Impériale des Sciences de St. Petersbourg. Tome VI. St. Petersburg, 1818. 4to.	Imperial Academy of Sciences of St. Petersburg.
Transactions of the Historical and Literary Committee of the American Philosophical Society, Vol. I. Philadelphia, 1819. 8vo.	American Philosophical Society.
Memoirs of the Connecticut Academy of Arts and Sciences. Parts 2, 3 and 4. New Haven, 1811—1813, 8vo.	Connecticut Academy of Arts and Sciences.
Flora Batava. Nos. 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51.	His Majesty the king of the Netherlands.
A specimen of the Meteoric stone which exploded over Weston in Connecticut, December 14th 1809.	George Gibbs, Esq.
Tour through Iceland in 1809, by William Jackson Hooker. London, 1810. 8vo.	W. J. Hooker, Esq.
Philosophical Transactions of the Royal Society of London. Parts 1 and 2 for 1819. London, 1820, 4to.	Royal Society of London.
A Memoir of Hugh Williamson, M. D. By David Hosack, M. D. New York, 1819, 8vo.	David Hosack, M. D.

PRESENTS.	DONNORS.
Tavole Trigonometriche di Giuseppe Toaldo. Paduæ, 1769. 4to.	W. Channing, M. D.
Commentationes Societatis Regiæ Scientiarum Gottingensis Recentiores. Vol. vi. Gottingæ, 1819, 4to.	Royal Society of Gottingen.
Philosophical Transactions of the Royal Society of London. Part 3 for 1819 and part 1 for 1820. London, 1819, 1820. 4to.	Royal Society of London.
Flora Batava. Nos. 55 and 56.	His Majesty the king of the Netherlands.
Kongl Vetemskaps Academiens Handlingar för Åren 1818, 1819. Stockholm. 8vo.	Royal Academy of Sciences at Stockholm.
Denkschriften der Königlichen Akademie der Wissenschaften zu München, für das Jahr 1811, 1812, 1813, 1814, 1815. Munich. 4to.	Royal Academy of Sciences at Munich.
Sketch of the Botany of South Carolina and Georgia. By Stephen Elliott. Charleston, 1816. 8vo.	Stephen Elliott, Esq.
Report upon Weights and Measures. By John Quincy Adams. Washington, 1821. 8vo.	Hon. J. Q. Adams.
Hermanni Witsii Ægyptiaca.	Fra. Vergnies, M. D. LL. D.
Jacobi Gronovii Geographia Antiqua, Dionsii Alex. et Pomponii Melæ Geographia, 1 vol. 4to.	" "
Hermanni Schlichthorst Bremensis Geographia Homeri, 1 vol. 4to.	" "
C. Salmasii Plinianæ Exercitationes, 1 vol. folio.	" "
Jacobi Sponii Miscellanea, 1 vol. folio.	" "
Sexti Empirici Opera, Gæce et Latine, 1 vol. folio.	" "
Miscellaneæ Observationes Criticæ in Auctores veteres et recentiores, 14 vols. 8vo.	" "
Schefferus de Re Vehiculari Veterum, 1 vol. 4to.	" "
Do de Militia Navali Veterum, 1 vol. 4to.	" "
Rubinius de Re Vestiaria Veterum, 1 vol 4to.	" "
Ferrarius, do.	" "
Winkelmann—Histoire de l'Art chez les Anciens. Translated from the German, 3 vols. 4to.	" "
La Place—Exposition du Systeme du Monde, 1 vol. 4to.	" "
Gossellin—Geographie des Grecs Analysée, 1 vol. folio.	" "
Grenet—Atlas Portatif, 1 vol. folio.	" "
D'Anville—Ancient Geography, 1 vol. folio.	" "
G. F. de Bure—Bibliographie Instructive, ou Traité de la Connoissance des Livres rares et singuliers, 7 vols. 8vo.	" "
Do. Supplement à la Bibliographie Instructive, 2 vols. 8vo.	" "
Falconet—Œuvres, 3 vols. 8vo.	" "
A marble Bust of Cicero,	" "
do. Tulliola,	" "
do. Cleopatra,	" "
do. Faustina.	" "

MEMBERS

ELECTED SINCE THE PUBLICATION OF THE THIRD VOLUME OF THE MEMOIRS.

RESIDENT MEMBERS.

Levi Frisbie, *Prof. of Nat. Relig. Moral Phil. & Civil Polity in Harv. Univ.*
Moses Stuart, *Prof. of Sac. Theol. in the Theological Seminary at Andover.*
Rev. Samuel Cary.
Andrews Norton, *Prof. of Sac. Lit. in Harv. Univ.*
Hon. Benjamin Pickman.
Rev. Samuel Willard.
Joseph G. Cogswell, Esq. *Prof. of Mineral. in Harv. Univ.*
Chester Dewey, *Prof. of Math. & Nat. Phil. in Williams Coll. Williamstown.*
Hon. Charles Jackson.
Walter Channing, M. D. *Prof. of Obstet. & Med. Jurisp. in Harv. Univ.*
George Hayward, M. D.
Rev. Bezaleel Howard.
Francis C. Gray, Esq.
Nathan Hale, Esq.
Rev. Edward Everett, *Prof. of Greek Lit. in Harv. Univ.*
Hon. Daniel Webster.
Francis Vergnies, M. D. LL. D.

HONORARY MEMBERS.

David Hosack, M. D.
Benjamin Silliman, *Prof. of Chem. & Min. in Yale College, New Haven.*
His Excellency the Chev. Jose Corea de Serra, *Min. Plenip. from Portugal.*
M. Fabre.
Horatio Gates Spafford.
His Excellency De Witt Clinton.
Sir Benjamin Hobhouse.
Dugald Stewart, Esq.
Daniel Drake, M. D.
Peter S. Du Ponceau, LL. D.

OFFICERS

ELECTED MAY 29, 1821.

Hon. JOHN Q. ADAMS, LL. D. *President.*

Rev. JOHN T. KIRKLAND, D. D. LL. D. *Vice President.*

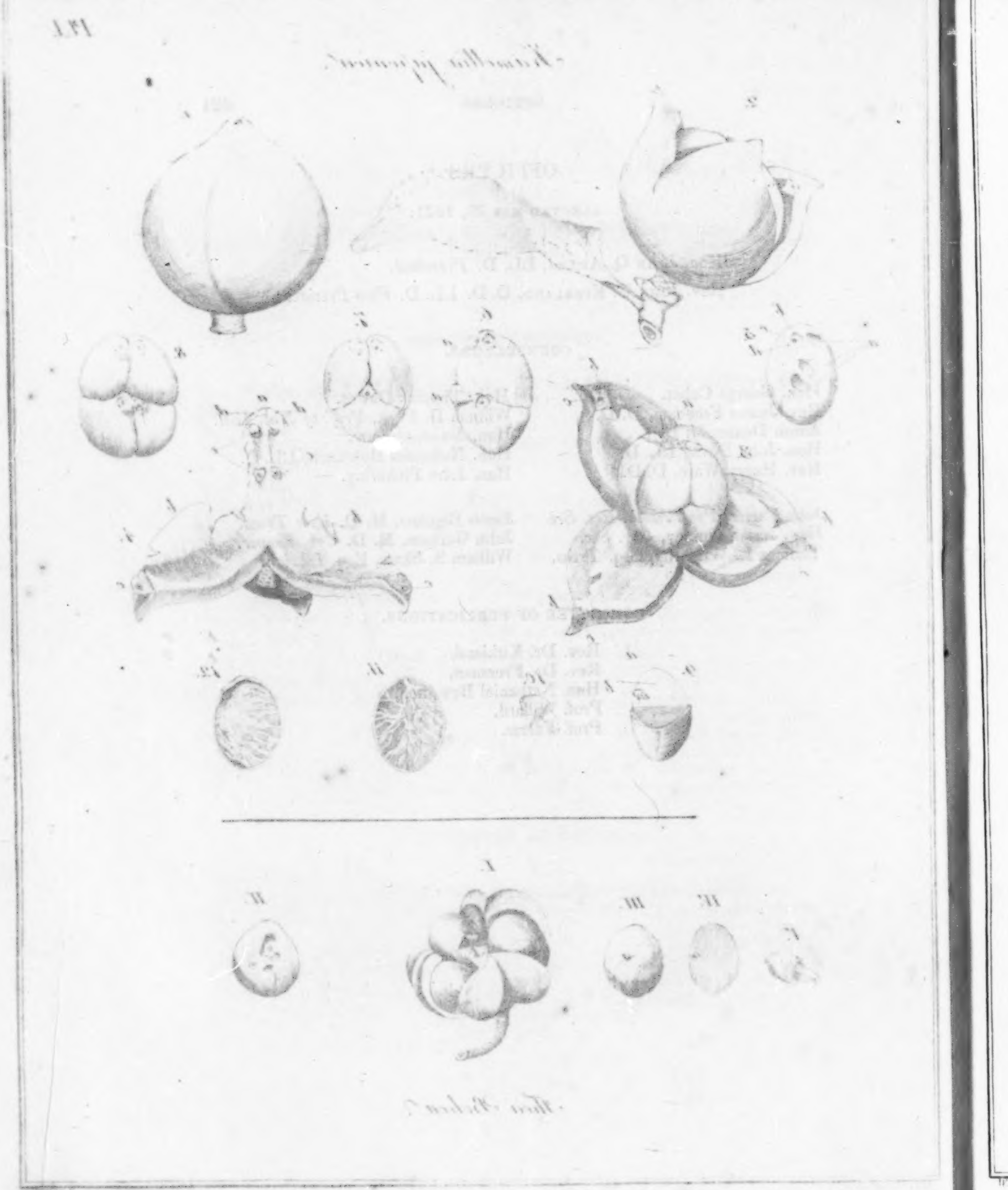
COUNSELLORS.

Hon. George Cabot.
Rev. James Freeman, D. D.
Aaron Dexter M. D.
Hon. John Davis, LL. D.
Rev. Henry Ware, D. D.
Hon. Thomas Dawes.
William D. Peck, *Prof. of Nat. Hist.*
Hon. Josiah Quincy.
Hon. Nathaniel Bowditch, LL. D.
Hon. John Pickering.

John Farrar, *Prof. Math. Rec. Sec.*
Hon. Josiah Quincy, *Cor. Sec.*
Thomas L. Winthrop, Esq. *Treas.*
Jacob Bigelow, M. D. *Vice Treas.*
John Gorham, M. D. *Cab. Keeper.*
William S. Shaw, Esq. *Librian.*

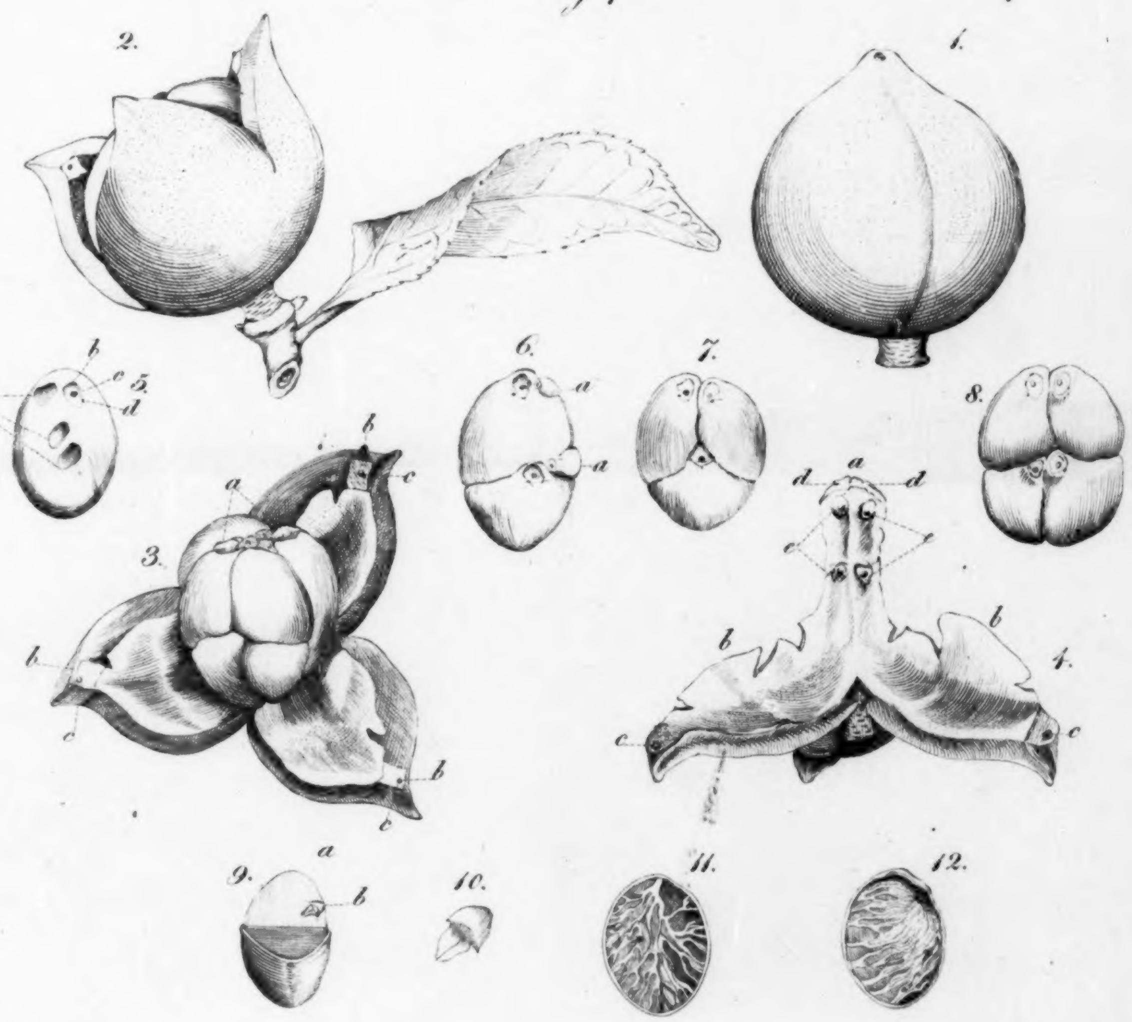
COMMITTEE OF PUBLICATIONS.

Rev. Dr. Kirkland,
Rev. Dr. Freeman,
Hon. Nathaniel Bowditch,
Prof. Willard,
Prof. Farrar.



Pl. I.

Kamellia japonica.



Thea Bohea.

W.D.P. Del. J.H.T. Sp.

Fig. 1.

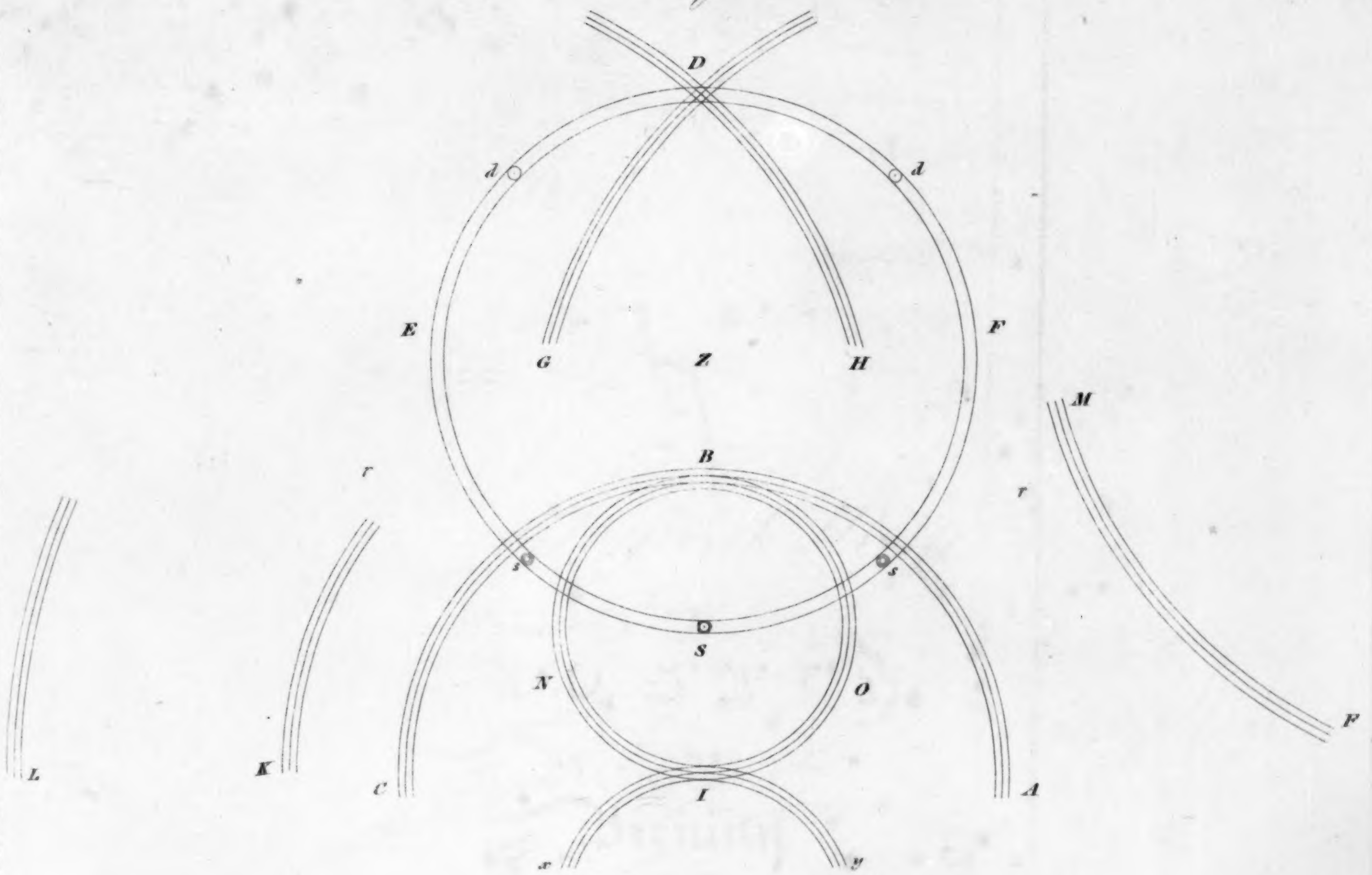
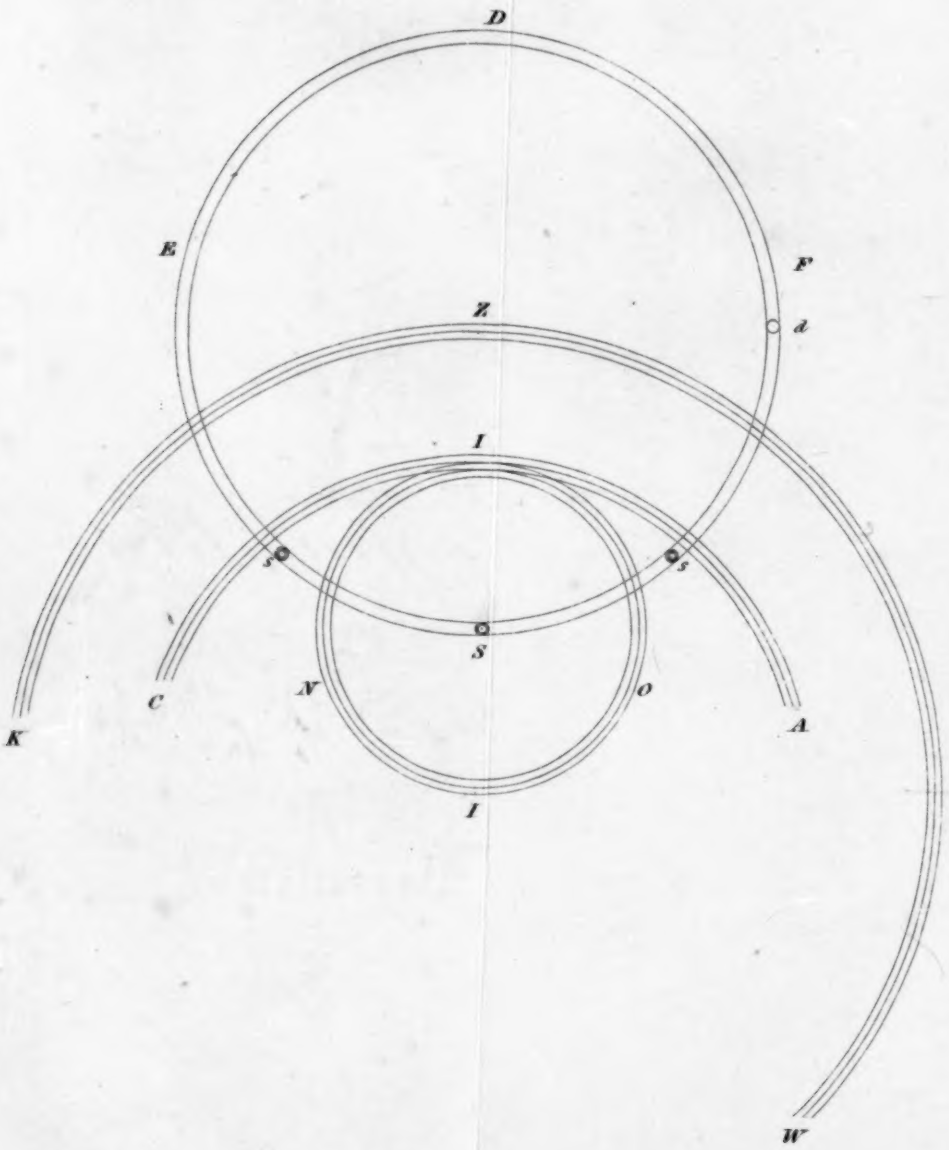


Fig. 2.



Wilmington
Billerica
Lynnfield
Reading
Burlington
Bedford
Woburn
Stoneham
Lexington
Medford
Malden
Lincoln
West Cambridge
Chelsea
Waltham
Charlestown
Watertown
Cambridge
BOSTON
Weston
River
Charles
Newton
Brighton
Brookline
Roxbury
Needham
Dorchester
Natick
Neponset River
Mother Brook
Milton
Dover
Dedham
Blue Hill


A Geological Map of Boston and its Vicinity
Engraved for Dana's Outlines of the Mineralogy and Geology of Boston
Annin & Smith Sc.
Sienite
Greenstone
Petrosilex
Porphyry
Greywacke
Amygdaloid
Argillite
Alluvion
Danvers
Beverly
Salem
Marblehead
Lynn
Egg Rock
Nahant
Chelsea
Pt. Shirley
Ft. Independence
Boston Light
Harding Rocks
Hull
Quincy
Hingham
Cohassett
Braintree
Weymouth

Τῷ λογιωτάτῳ Κυρίῳ Ἰωάννῃ τῷ Πικκερίνγ.

Κύριέ μοι χαῖρε.

Ἐγὼ ἤδη ὅτι, καὶ τὰ ἀξιολογώτατα ἐδῶ σχολεῖα σας νὰ μὴν ἔχουν τὴν παραμικροτέραν διαφορὰν ἀπὸ ἐκεῖνα τῆς Ἀγγλίας, τόσον εἰς τὰ φιλοσοφικά, καθὼς εἰς τὰ ποιητικά, καὶ τί λέγω; γυμνασμένοι ἀπὸ κάθε λογοῦ διαλέκτου καὶ ἀξιοτέρων ἐπιστημῶν· καὶ ὄντας μετ' ὅσα αὐτὴν μάθησιν ἤκουσα νὰ ἀναγνώσουν, τὴν ἑλληνικὴν διάλεκτον, μὲ ἀνορθώτατας συλλαβάς, μὲ παρ' ὀξείας, μὲ ἀσύμφωνα τοῦ λόγου, καὶ σχεδὸν μὲ παντάπασι ὀρθῆς γραφικῆς ἀκοῆς. Ἄρα λοιπὸν δικαίως φρονῶ ὅτι λέγω, ὅτι τοὺς ἦτο ἀναγκαιοτάτη καὶ αὐτῆς ἡ μάθησις. διὰ τοῦτο καὶ ἐπρόσφερα τὸν ἑαυτόν μου, πρὸς τὸ εὔκλαμπρον γένος, καὶ ὑπεσχέθην εἰς ὅσους ὅσοι ἐπιθυμοῦν νὰ παραδώσω τὴν αὐτὴν γραφικὴν προφορὰν, ὡς ὅπου εἶμαι γέννημα τῆς Πελοποννήσου, ἐκ τῆς πολιτείας κατὰ παλαιὰ Πύλου νῦν δὲ Ναβαρίνου, καὶ ὅπου εἰς τὰ ἴδια μέρη αὐτὴν τὴν διάλεκτον καὶ προφορὰν ἐδιδάχθηκα.

Πρὸς τούτοις λέγω ὅτι ἐκτὸς τῆς παραδόσεως τῆς προφορᾶς, ἤμην καὶ τινὰς ἀγάπα, καὶ τὸ νὰ γράφειν, θέλω τὸ παραδώσω τὸν τρόπον τοῦ παρὸν χαρακτῆρος μου, ὅστις ἦτο καθ' αὐτὴ εἰκόνα ψηφίων γραμμάτων, ὅπου συνηθίζει εἰς τῆς Ἑλλάδος ἑλληνικὰ σχολεῖα μας. Ταῦτα, καὶ μὲ ὅλον τὸ σέβας προσκυνόντας σας μένω.

Μπόστον τῆς 2 Φεβρ. 1818.

τῆς λογιότητός σας
ταπεινότατος δοῦλος
Νικόλαος Τζικλήτρας.